HIGH-TEMPERATURE SUPERCONDUCTIVITY TECHNOLOGY TRANSFER

HEARING

BEFORE THE

SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDREDTH CONGRESS

-SECOND SESSION

JUNE 23, 1988

[No. 118]

Printed for the use of the
Committee on Science, Space, and Technology

U.S. GOVERNMENT PRINTING OFFICE

89-072 WASHINGTON : 1988

For sale by the Superintendent of Documents, Congressional Sales Office
U.S. Government Printing Office, Washington, DC 20402

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HIGH-TEMPERATURE SUPERCONDUCTIVITY TECHNOLOGY TRANSFER

THURSDAY, JUNE 23, 1988

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT,
Washington, DC.

The Subcommittee met, pursuant to call, at 9:30 a.m., in room 2325, Rayburn House Office Building, Hon. Marilyn Lloyd [Chairman of the Subcommittee] presiding.

Mrs. LLOYD. Good morning, everyone. The Subcommittee on Energy Research and Development will come to order.

It's pleasant to see so many familiar faces here so early on this summer morning. I know that many of you followed our authorization hearings with great interest, and I'd like to note that our Committee's energy R&D authorization bill passed the House by a 290 to 27 margin—we're very happy about that—on June 3rd, and our bill was transmitted to the Senate. We hope that the Senate will see its way in reporting a similar bill for joint consideration.

I'm sure you're also aware that both the House and the Senate have passed Energy and Water Appropriations bills and these bills are now in conference. The budget climate, of course, was very tight this year, and several of the new projects that we authorized are conference items in Appropriations, and we're hopeful that the final Appropriations bill will be along the line of the House-passed authorization bill.

This hearing is in the nature of an oversight snapshot on a topic that the Subcommittee Members—indeed, most of the Congress—are interested in, that of high-temperature superconductivity applications. It has been about a year since the President announced the initiative for this program, asking the Department of Energy laboratories specifically to support the program and help American industry compete in this area.

The Subcommittee strongly supports the use of the DOE laboratories in this very vital area, as it has supported a high-temperature superconductor applications program just being initiated by the Department. Government R&D applications programs where the Government is the user of the applications can result in the creation of major new industries.

What we would like to do today is to check on the status of these activities and determine where the process is flowing smoothly and where problems might be developing. We especially want to hear

industry's views since, after all, they are supposed to be the major agent of the commercialization process.

There is one problem that I know about and can update. It concerns the recent freeze by the Department of Defense on new contracts. On June 15th, I wrote a letter to Secretary Carlucci expressing my concern about the freeze effect on research, development, test, and evaluation contracts, specifically citing the key initiative in R&D on high-temperature superconductors.

This Tuesday, the Deputy Defense Secretary, Mr. Taft, appeared before the House Armed Services Committee, of which I am also a Member. In responding to my questions, Mr. Taft indicated that the freeze would be partially lifted July 1st on a case-by-case basis, including funding for the high-temperature superconductivity activities. So there does appear to be some relief on this problem which severely impacts some of the industry witnesses that we will be hearing about today.

I would like to introduce my friend and colleague, Sid Morrison, a little bit later. He is not here at this time, but we will insert his remarks in the record at the appropriate time.

We do have a lot of things going on, as you know. We have two or three places we are supposed to be at one time. We haven't figured out how to do it yet, but we will report back as soon as we do.

But with this framework provided, I do want to welcome our first panel, that of the Government agencies, DARPA—the Defense Advanced Projects Research Agency, SDIO—the Strategic Defense Initiative Organization. DARPA is represented by its Deputy Director for Research, Dr. Craig Fields, and SDIO is represented by its Chief Scientist, Dr. O'Dean Judd.

Unfortunately, the Department of Energy was unable to send a policy spokesman, and so I do ask unanimous consent that the written statement of Miss Donna Fitzpatrick be included in the record.

Dr. Bill Gallagher from IBM could also not be present today, and I ask unanimous consent that his written statement also be included.

[The statements for the record of Miss Fitzpatrick and Mr. Gallagher are contained in the Appendix.]

Mrs. LLOYD. Now I would like to introduce my good friend and colleague, Mr. Morrison.

Mr. MORRISON. Thank you, Madam Chairman. I am delighted to be part of this hearing today. The topic is so very timely, and I have an opening statement. I would like to ask that it be made part of the record and look forward to the agenda the staff has put together for us.

[The opening statement of Mr. Morrison follows:]

OPENING STATEMENT OF HON. SID MORRISON

Good Morning. I am delighted to be here as our Subcommittee conducts this hearing on superconductivity today. Only eight months ago we heard from the President's Science Advisor and witnesses representing the Federal Government, National Laboratories, universites, and industry on the progress in superconductivity research and development, the timing of commercialization, and the roles they played in the development of superconducting materials. I believe the insight be gained from that hearing has enabled us to focus on the major issues and challenges we are facing today, and to set some priorities for handling them.

Over the last two years, there has been a rapid increase in our understanding of high-temperature superconductivity as well as our funding for this research. The President issued his eleven-point superconductivity initiative last July, and outlined a plan to promote future work in superconductivity and ensure our Nation's readiness in commercializing this technology. Both the Department of Energy and Department of Defense have shown their commitment to developing high-temperature superconducting materials, and directed the National Laboratories to move toward high-temperature superconducting devices for civilian and defense applications. We still have to struggle to gain a competitive edge, especially over the Japanese, but we certainly have made some good progress toward their direction.

Madam Chairman, I think this is a good time to take a look at how well we have done so far to develop high-temperature superconducting materials and commercialize this technology, and to determine how to make the most of our investment. Because each Government agency has its our applications program and its own plan for technology transfer, I am anxious to find out how effective these programs are, and How well the agencies coordinate their efforts to accomplish the goal of commercialization. From the industry perspective, I also look forward to hearing now technollogy transfer from National Laboratories can enhance business opportunities and international competitiveness. I believe the distinguished witnesses here will shed some light on these important areas.

Mrs. LLOYD. And it is good to be here this morning.

PANEL 1: DEPARTMENT OF DEFENSE

Gentlemen, you are our first witnesses, and you can provide your statement and proceed as you wish.

Dr. Fields.

STATEMENT OF DR. CRAIG FIELDS, DEPUTY DIRECTOR FOR RESEARCH, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY, U.S. DEPARTMENT OF DEFENSE, WASHINGTON, DC

Dr. FIELDS. Good morning.

I appreciate the opportunity to come and tell you about DARPA's superconductivity program. We have two members of the staff with me today. I'd like to introduce Lisa Niesz and Kay Rhyne, both of whom are behind me—Lisa Niesz from the Director's Office, and Kay Rhyne from the Defense Sciences Office. Dr. Rhyne is, in fact, in charge of our high-temperature superconductor program and is the person who deserves credit for what I consider an excellent program that we'll be able to describe this morning.

When I testified here on the 10th of June of last year, I told you that what we were going to try to do was to develop as quickly as possible an industrial technology base, processing, fabricating, and manufacturing these new ceramic superconductors, and that's exactly what we've been proceeding to try to do.

In your letter of invitation, you had a set of questions that you wanted me to address. I've put together an agenda of four parts to try to address those questions. First, I want to tell you about the general philosophy and approach of our program; then I want to tell you what's actually in the program in terms of contractors, some of the work, some of the schedules, some of the accomplishments to date.

Thirdly, I'd like to tell you about our relationship with some other programs and other activities. The area of high-temperature superconductivity is one which is extraordinarily well coordinated within the Government, not because of any outside imposition of

that coordination, just because it's a natural and good thing to do, and it's working really quite well.

Then, lastly, I want to address the last issue you raised—namely, opportunities and problems—because there are certainly some things to say there.

Let me start off with philosophy. As you know, what DARPA does is to give contracts to companies, to universities, other laboratories, develop technology where there's some high risk but also some high impact. In a sense, we serve like a source of venture capital to try to do things where the risk is sufficiently high that private sources of capital just won't step in. We step in for a period of time until the risk is a little lower, and then private sources of capital pick it up, or other parts of the Government in some cases.

Primarily, we fund industry. We do fund universities; we do fund National Laboratories, other kinds of laboratories, but primarily it is the industry, and thus the issue of technology transfer is not quite the same for us as it is for other organizations where they predominantly fund non-industry organizations then have to transfer to industry. We go right to the place where they are going to use it later. I'll tell you about that when we get into our actual program.

In doing so, we have evolved a simple but, I think, effective means of protecting the intellectual property rights and the proprietary rights of the companies involved, because we want to motivate them to later fund the work. We want to motivate private capital sources to later invest in the work, and so that's something that we do within the restrictions that DOD applies, and those restrictions are actually quite lenient in this case. We can, for the last few years, for example, give companies as a matter of option in contracts the patent rights to the work that they develop during the contract, and that turns out to be a very powerful motivating force, and it works quite well.

Also, our staff—in this case, Dr. Rhyne—takes a very activist attitude toward building teams. It's not simply a matter of receiving proposals and funding the best ones and not funding those that are quite up to par but forming teams among companies, between companies and universities, companies and National Labs, and so on, and, where it makes sense, to actually include within the contracts deliverables to other members of the team, so that this isn't just a matter of good will but a matter of record.

One of the topics that has come up with this program repeatedly that I'd like to address explicitly is the question of whether we're pursuing so-called dual use technology—namely, technology which concurrently is of value to the commercial sector and to the military sector. In fact, that's the case in every one of the efforts, all 36 of the efforts that I'm going to tell you about today, and that's a statement of the state of the technology. It's simply too early to do something that's absolutely specialized for the commercial sector versus the military sector. Some time in the future, that difference may arise, and then we'll have to reexamine the whole question, but right now that is just not a problem.

I'll give you one example, the case of SQUID's, these so-called superconducting quantum interference devices for detecting magnetic fields, very low-intensity magnetic fields. We're doing work which,

on one hand, is important for the military for detecting mines and submarines; on the other hand, is important for geologists in finding ores and important to the medical profession, doing a new generation of technology for brain scans, and so on and so forth. I can give you many other examples, but within the 15-minute restriction that you asked for this morning, I really can't go into it.

I told you that we were concentrating in the area of manufacturing, manufacturing technology. We're doing that at the same time that other parts of the Government are funding work in basic theories, science, finding new materials, studies of applications, and so on, because we want to have a Government-wide balanced program even if each individual effort might be skewed in one direction or another. So we are concentrating on processing, on fabrication, on issues of scale-up, issues of quality, issues of process control, cost effectiveness, and so on.

In doing so, we are taking a small risk, because when we do engineering at the same time as science, it's always possible that the science will find something that obviates a lot of the engineering you did earlier. To date, that hasn't been the case. As people working in university laboratories, for example, have discovered new superconducting materials based on bismuth, or thallium, or what-have-you, we have found that we can quickly pick these new materials, and, using the same kind of ceramics processing technology that we were developing, include them in our program, and so things have been working quite well in that respect.

Now I want to say one word about applications to end this introduction—namely, there is a lot of talk about doing applications and just where the technology is. From my point of view, you can sensibly speak of doing applications when you have an industrial base and you're not trying to do the engineering to combine components from that industrial base to build a useful system. We are not there yet. We are at the point of trying to develop that industrial base, trying to develop those components and make them available. We will be, I hope soon, but we're not there now.

So what we're now doing about applications is studying them, figuring out just what are the characteristics we need for the components and for the materials so later we can have useful applications. I wanted to clarify that statement of just where the technology is from our point of view.

Let me now turn to what's actually in our program. I want to start with some overall statistics to give you a feel for what's there and then go into some details.

The program consists of 36 different contracts involving 34 prime contractors; two got two contracts; and then there are perhaps 15 subcontractors as well. So it's a fairly large effort. It's an effort which is predominantly industry, 72 percent of our Fiscal Year 1988 funds go into industry, and we expect a comparable percentage in the future. It's a program that's split between large companies and small companies, in fact, almost 50–50–44 percent to small businesses, the rest to large businesses. Interestingly, it's also a company which is bringing into the defense process, firms that previously weren't involved. Almost exactly half the companies involved are not traditional defense contractors; the other half are traditional defense contractors.

Mrs. LLOYD. Why is this so, Dr. Fields?

Dr. FIELDS. Well, I think there are new skills that are needed for doing this work that haven't been really required for defense technology to date, and so it becomes a natural part of the process. I'm pleased because that means that we can get new talent applied to defense issues, which is, of course, our main line of business, but, on the other hand, that also means that defense support is, as a spinoff but a very real and large spinoff, aiding commercial development. So it works both ways.

Now the status of things is that, of those contracts, 24 of the activities are now under way and 10 of them are not now under way as a consequence of the freeze that you talked about earlier, and we'll just see what happens about that later this week and later that month. I don't want to predict, because I have no means of doing so.

However, of the 24 that are now under way, fully two-thirds are on so-called early starts—that is, before the last "i" is dotted and "t" is crossed on the contract, the contracting officer has allowed the company or university to begin work at their risk at a certain level of effort. That's good because the work is going on, but it's bad because they are at risk. Depending on what actually happens, I hope that we will be able to finally sign the contracts before they run out of this allocation of at-risk money. Again, that remains to be seen.

Now the program is organized into two parts, a little part and big part. The little part is general materials support for processing and fabrication of these materials; the other part is dealing with particular components, and I'll get to that in a moment. In terms of the materials support, we're dealing with both thin-film and bulk materials. We have four contracts, four efforts, concerned with thin films with the following organizations: Advanced Technology Materials, Cornell University, North Carolina State, and Rockwell International; we'll supply these for the record later. I just want to give you a sense of the organizations that are involved.

In the case of the bulk superconductors where there are some different problems, we're dealing with Ceracon; MIT; Multiarch; National Bureau of Standards; SRI, International; Temple University—again, a wide range of talent represented.

That forms a minor part of the program, because we really wanted to concentrate on the aspect of developing components efforts. Our components program is divided into ten pieces, and I'd now like to go through those pieces, and it's in declining priority order. We've had to establish priorities, because, in fact, there's always uncertainty about funding, and we wanted to have a regular means of deciding what to do if we got more or ended up getting less, and priority does that for us.

Starting off, we have an investment with two large contracts for A-to-D converters, again, useful both in the commercial sector and the military sector but, in fact, with Hughes and TRW; four efforts in analog processing devices with Lincoln Laboratories; Superconductor Technology, Incorporated; Varian; and JPL, JPL at CalTech. Then only one contract in gyroscopes and accelerometers with Honeywell. Honeywell is one of the two organizations that had two efforts, the National Bureau of Standards being the other

one. Then a very exciting investment with three contracts in digital processing devices, digital circuits, one with Hypress, one with the University of California at Santa Barbara, one with the University of Oklahoma.

This is particularly interesting to me personally because we've been, in our strategic computing program, doing a lot of work on computer architecture, how to combine components in different ways. We've been doing calculations to see what would be the effect of these new architectures combined with the new superconductors, if we can get that to work, and we end up with just absolutely fantastic numbers, single computers that dwarf the whole computing capacity now available in the United States, for example, and that's years off because we had a lot of problems to overcome, but we know there's a pot of gold at the end of the rainbow, and so it's really worth pursuing.

Going on to the fifth area, we're investing in motors, two efforts, one with Allied-Signal and one with CPS, Ceramics Processing Systems. Next, one effort in bearings with Eastman-Kodak, and two efforts in SQUID's; I mentioned those earlier, one with Biomagnetic Technologies, the other with the Naval Research Laboratory; and five efforts in magnets and sort of energy storage devices; American Magnetics, Boeing, General Electric, Los Alamos, and Monolithic Superconductors. Then two efforts in RF cavities and antennas, one with General Atomics, one with Westinghouse. And, lastly, the tenth area, in IR sensors we have just one effort with Honeywell.

Now in addition to those, we have two centers of excellence at universities, major efforts we're very pleased with, one at the University of Houston and the other a consortium of Florida universities, and those are going along quite well.

That's the scope of the program. How it goes in the future depends on the performance of the contractors, depends on our funding levels, and so on and so forth, but we're off to a good fast start. In fact, this is the second wave of contracts because, as you may recall, soon after these materials were invented or discovered we were able to get ten earlier contracts going, and they've now phased into this much larger effort.

Now this program is unusual in my experience for a research program in that it has the kind of things you normally expect from major construction projects. There's a schedule of events, and there are deliverables, and there are milestones and decision points, and so on, and priorities, as I indicated. I'm very pleased about that because I think this is too important to fool around with. We have to deal with it in a serious manner. Dr. Rhyne deserves all the credit for that.

I can't really go through all of the milestones on the schedule, but I want to give you just a couple of indicators. For example, now we have a basis for the belief that we're going to have much better processes for producing high-temperature superconducting powders in Fiscal Year 1989. That's pretty serious because not only are they important for our use but right now the best source of supply is a French company, Rhone Poulence, and we would like the situation to be different.

To give you another example, in Fiscal Year 1990 we have good reason to believe we're going to be producing 3-horsepower and 50-horsepower motors. When I spoke a year ago, we knew we wanted to do motors but we didn't know at what performance and when. Now we know something about performance and we know something about when, and that's good progress, and there are lots and lots of other milestones as well. Again, time doesn't permit reading that.

We spent a lot of effort on dealing with the issue of technology transfer to the military because we are in the Defense Department, and so we have a whole schedule of events for what we hope to transfer when to what service. For example, in the fairly near term, less than three years, we hope to be involved with the Navy and SQUID's for the applications I mentioned earlier, and in a later time frame, three to five years, we're talking with all the services about using A-to-D converters, various front ends for processing devices, chip filters to the Air Force for EW applications, and, again, a whole long list. So we formed these links and liaisons going down that track.

Now in terms of accomplishments, when I asked Kay for what has happened to date, even though time has passed, I was pleased to see that there was a rich set of things. Again, I'm not going to be able to go into all of it but just give you a sampling. To me, perhaps the most exciting thing is the work of several contractors in developing low-temperature processing techniques for putting thin films of superconductors on substrates like silicon and gallium arsonide. The problem to date has been, you needed a high temperature to make it, with the high temperature of the substrate diffused into the superconductor and it no longer superconducted, and that's not good, because then you couldn't produce the hybrid devices which are part traditional electronics, part superconducting, but now at least two organizations, North Carolina State and the University of New York at Buffalo, have been able to produce low-temperature means of producing that, which is one of the many steps we will have to go through in order to actually make this practical.

There are lots of other applications in terms of reducing the high-frequency loss of the material. I think Cornell has a technique for getting the loss material for transmission for high frequency down by a factor of ten less than copper, and copper is now the standard that is used in many cases. So there is real improvement there. I have many, many other examples to go through some time later.

Now I want to turn to the third topic and just leave the program for the moment, although we can certainly discuss it later if you seek to get into some more technical detail, and talk about our relationship to other programs.

Within the Defense Department, there is a formal committee that is headed by the Deputy Under Secretary for Research and Advanced Technology and practically headed by Ted Berlincourt which meets periodically to see that within DOD we remain coordinated and we have a balanced DOD program even if each piece does more of this or less of that. We also, from a Government-wide point of view, meet in a committee called COMAT, Committee on

Materials, OSTP. That's working fine. We have our own personal contacts at the Department of Energy, and, in fact, there are joint activities, for example, National Labs, Oak Ridge, and Los Alamos, working on motors and coordinated with our contractors working on motors.

We are also working closely with the National Bureau of Standards, in part because we are funding a good deal of their work, so that's a natural linkage, and then we have our contacts with the National Science Foundation where, in contrast to our more applied work on facturing, they're dealing with theory or university-based laboratory work and also at NASA where they're concerned with some special space applications.

Predominantly, the Office of Naval Research, our partner in this, has been the agent for this program, but, in addition, we've dealt directly with Government labs, the Air Force Office of Scientific Research has served as an agent, and DARPA's own contracting shop has done that as well.

Recently, there was a study conducted by the Defense Science Board looking at military applicability of these materials, because we wanted to make sure they really would go some place, performances we could expect. The report will be out in July. We, of course, have a preview of it. It's a very positive report, and I'm pleased with the effort that they've made.

Lastly, we also work very closely with the venture capital community—it's something where I can't go into details because of commercial interests—trying to have joint funding where we'll do the early stages; I mentioned earlier they'll do the later stages; and there are a number of absolutely real partnerships in that respect.

I want to deal with the fourth subject that I promised for the morning—namely, opportunities and problems in our program—and there are probably three that are worth mentioning. Number one, as you'll recall from our large-scale procurement, we received 203 proposals, including many more subcontractors, requesting $330 million in a sort of two- to three-year beginning of the program time scale. About half of those proposals were really excellent; the other half were a little less so. Of the half that were excellent, we've ended up buying about a third of those. Two-thirds of those excellent proposals we just couldn't purchase. I wish that weren't the case. I hope that other parts of the Government can pick those up. Perhaps some time later we'll be able to pick those up. It's just too expensive to ignore two-thirds of an excellent talent pool—definitely an issue.

The second issue is that there's a whole area of research and technology development which we're not yet investing in, which I'll call infrastructure, which is not the materials and the production of the materials themselves but things around it that may spell the difference between a practical technology and an impractical technology. The best example there is cryogenic-cooling technology. For a while for some time to come, we expect that, in fact, some cooling will be needed for these materials, and the better the cooling technology the more practical various systems are in terms of volume, weight, cost, and so on. That's something we'd like to expand into but we're not doing so at this time.

And the last issue is the one you raised—namely, the current freeze within DOD. We'll just have to see how that plays out. That's a particular problem for small companies where I get calls frequently about possible lay-offs—in fact, real lay-offs—and it's a lot faster to fire someone than to rehire them. That's something that I hope we'll be able to solve soon.

Those are my comments for this morning. Thank you.

Mrs. LLOYD. Thank you very much, Dr. Fields.

Dr. Judd.

STATEMENT OF DR. O'DEAN P. JUDD, CHIEF SCIENTIST, STRATEGIC DEFENSE INITIATIVE ORGANIZATION, U.S. DEPARTMENT OF DEFENSE, WASHINGTON, DC

Dr. JUDD. Thank you, Madam Chairman. It's a pleasure to certainly appear before your Committee today to discuss the Strategic Defense Initiative's program in high-temperature superconductors, and particularly these important issues related to technology transfer.

Now SDI is certainly very enthusiastic about the high-temperature superconductivity R&D, and with me this morning I'd like to introduce the program manager at SDI for at least our high-temperature work, Dr. Clyde Northrop back here.

Mrs. LLOYD. We're happy to have you with us.

Dr. JUDD. We feel strongly that there will be very many important developments in this area not only for SDI but for also the rest of the defense community, and these developments will certainly spill over into the economic sector.

Now in putting together our program in SDI, we recognized that we're certainly up against international competition, and particularly from Japan, and so we took a look at their program and certainly realized, as I'm sure many of you have, that they're basically pushing forward in three areas. They're coordinating all of their various potential sources of expertise—universities, private industry, their Federal laboratories. They're certainly establishing seven- to ten-year funding cycles. They've committed funding requirements, and they're doing significant marketing surveys to try to identify where the product lines were going to be.

We've taken the same approach in SDI. We've formulated our programs around that, decided that we really can't do business as usual here, so we're pushing forward in a number of things in parallel, and I'll go through those here in my overview comments. But I think this is particularly important in view of our constrained budgets that we're currently faced with, and it behooves us all then to certainly capitalize on our unique expertise and teaming arrangements that we have in the country.

Now SDI has very unique needs for these particular kinds of technologies. One example is the large focal plane arrays that we developed for infrared detection. These, we believe, with future developments in high-temperature superconductivity, can be made considerably simpler, cheaper, all of the things that we'd like, including putting on the data processing, things like that, perhaps even to the point of putting it all right on the focal plane. So there are very important unique applications.

However, again, we anticipate a lot of these applications will be useful in other DOD applications and hopefully into the commercial sector.

Now SDI has actively funded a number of low-temperature superconductivity programs over the past years even before the advent of the high-temperature superconductivity work. We're continuing to do that. We think that they're very synergistic in many ways. We've heard some of them already mentioned this morning. We're pursuing the same kind of thing. We have about $13 million in the high-temperature work, about $4 million in the low-temperature, and we feel that it's really essential to pursue both of these activities synergistically.

Now we have three objectives for the SDI program: basically, to identify high-temperature superconductivity applications that have major benefits on SDI programs; certainly to indicate where we need the critical research and development necessary to push these early prototypes; and, finally, to integrate all of these technologies into our Strategic Defense elements and into the systems as early as possible, and to do that, what we've done is, we've divided the high-payoff areas roughly into three areas: small-area devices, electronic devices; larger-area components; and high-current, high-energy components—magnetic shielding, power generation, and things like that. And what we did is form program oversight groups in each of these categories, and we solicited strong participation by other Government organizations.

These particular groups within SDIO are called technology-insertion working groups, and in addition to pushing and making sure that we're moving out on the basic research, these people are also tasked with pursuing very actively device engineering and issues of producibility, manufacturing. And the membership in these groups is spread across many Government lines, including DARPA, the Air Force, Navy, Army, the National Security Agency, the National Aeronautical and Space Administration, and the Department of Energy.

Now in order to provide component development, what we're doing is encouraging competition between teams that are drawn from industry, universities, and Federal laboratories, and roughly our financial support is divided equally between these sectors, and, again, the idea is to emphasize not only the basic research but the engineering of device development and systems and production issues and do that in parallel right at the beginning of the development cycle.

Now there's a fourth element of this that I'd like to stress, and that is the producibility of these components. In order to address this, we've brought together another group, another concept, called Manufacturing Operations Development and Integration Laboratories, or MODIL's. Now the idea would be to have these MODIL's operate with centers around the country or consortia but to focus on the producibility issues, manufacturing issues, as we need them, and these teaming arrangements are going on now; they'll continue to go on.

Mrs. LLOYD. Let me get something. Your teaming arrangements, are they industry and universities and labs together, or are they competing? I didn't understand that.

Dr. JUDD. The way it's set up now is that they would form those together and then have various teams of those.

Mrs. LLOYD. Thank you.

Dr. JUDD. But no. We try to bring in the elements of all of the various expertise into one team.

There's an example of this and the reason for doing this in this way. In materials engineering, in order to proceed rapidly, we believe that you're dealing with scientifically-complex materials here, and what that requires is access to scientific expertise and also a fair amount of sophisticated instrumentation to push these things forward, and rather than duplicate this we're trying to form teaming arrangements in which we can best utilize both the expertise and the scientific equipment that we have available.

Now a lot of this scientific equipment and expertise we find in the universities and the Federal laboratories, for example, and what we are trying to do is team those particular people up with the people in industry to push forward with an integrated approach on these things, and what we hope to do on this is to be able to disseminate this type of information throughout all of the interested parties in the U.S., and particularly in that way we're able to give that information both to large industrial concerns and small businesses. That's a way of getting it across—the information out across the board.

Now SDIO traditionally has had a technology transfer program for a number of years here, and this particular tech program has been designed, and we have a specific group in SDI, to make sure that we transfer all of our technologies, SDI out to industry, and the high-temperature superconductor work would also be included. To date, that's been very effective. We have a number of efforts that have gone out into the commercial sector from SDIO, and we hope to continue with that.

Now in the area of problems issues there are the obvious ones, and that is stable Federal budgets, and we need a streamlined contracting process to address these national priority problems. To certainly ensure success, excellence, and dominance in this area, I think stable long-term R&D funding is essential. It's essential not only because there are enormous inefficiencies and delays in teaming arrangements, contracts, research programs, but it's basically also bad on the morale of the investigators, particularly true in the basic research, so we absolutely have to have some stable funding in these areas, and I think we have to take our example from the Japanese. Okay.

Now in terms of Government cooperation, we've had excellent results in this area. I already mentioned a lot of the areas that we're working with. These arrangements are very effective not only in contracting, cooperative funding, but in terms of communication, spreading information; that's all going very well; and, again, SDI also is certainly strongly coupled with the Committee on Materials in the Office of Science and Technology Policy, and that seems to be going well.

Finally, I'd just like to conclude my statement here by saying that again we're very enthusiastic about the high-temperature superconductivity work. We think it's going to have major impacts in SDI and other DOD organizations, and we're making a strong

effort to not only couple these together in the Department of Defense but to try to integrate all of our expertise around the country in terms of private industry, Federal laboratories, and the Government agencies.

Thank you.

[The prepared statement of Dr. Judd follows:]

STATEMENT ON

HIGH TEMPERATURE SUPERCONDUCTIVITY TECHNOLOGY

AND

THE STRATEGIC DEFENSE INITIATIVE

BY

DR. O'DEAN P. JUDD

CHIEF SCIENTIST, STRATEGIC DEFENSE INITIATIVE ORGANIZATION

BEFORE THE

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

100TH CONGRESS, SECOND SESSION

JUNE 23, 1988

Madam Chairman, thank you for this opportunity to appear before your Committee today to discuss the Strategic Defense Initiative's (SDI) Program in High Temperature Superconductors (HTS) and the important issue of technology transfer. The initial breakthroughs in HTS occurred in 1986 and early 1987; since that time, this revolution in science and engineering continues unabated, and appears to be accelerating. We are rapidly increasing the numbers of families of High Temperature Superconductors and moving towards HTS devices and applications. This development has great potential for applications both for the defense and economic sectors.

The United States is facing a major international competition in the development of HTS components, and currently the Japanese appear to be the strongest competitor. The Japanese strength is derived from (1) coordinating their national laboratories, industries and universities in cooperative efforts, (2) establishing 7-10 year funding cycles with strongly funded commitments, and (3) focussing their talent on market targets.

In order to maintain a competitive edge, the United States cannot assume "business as usual." To succeed in this international competition with the current budget constraints, it is imperative that we consolidate our resources and capitalize on our unique strengths.

THE SDI HTS PROGRAM

The SDI program has a number of unique, critical requirements such as long wavelength infrared detectors/electronics and space-based radars which will be impacted by HTS, that would not ordinarily be developed by the commercial sector. However, we anticipate substantial spinoffs for other DoD applications as well as the commercial sector.

The SDI has actively funded a number of Low Temperature (4 Kelvin) Superconductor (LTS) applications even before the discovery of HTS. Our current HTS device work builds on this LTS technical base and scientific expertise. Many of our HTS device concepts can be tested first as LTS analogs, because we can reliably build and test these quickly. It is essential that superconductivity in general (both LTS and HTS) be supported if we are to realize the overall system benefits of superconductivity rapidly.

The goal of the SDI HTS program is (1) to identify HTS applications that have major benefits on SDI programs, (2) to initiate the critical research and development necessary to achieve early prototypes and (3) integrate of these technologies into Strategic Defense System elements.

Within the SDI, the potentially high payoff components were divided into three categories: (1) Small Area Devices, (2) Large Area Components, and (3) High Current, High Energy Components. SDIO formed program oversight groups for each of these categories which solicited strong participation by other government organizations. We call these groups Technology Insertion Working Groups (TIWG's). In addition to facilitating the basic research required for SDI components the TIWG's are responsible for integrating the basic research efforts with device engineering, system, and production issues for the ultimate hardware. The TIWG's emphasize both long range goals and intermediate applications. This program therefore allows early production and field experience to be obtained. Members of these TIWG's included SDI Program Managers, and key representatives from DARPA, Air Force, Navy, Army, National Security Agency, National Aeronautical and Space Administration, and the Department of Energy.

In order to provide component development, the SDI is encouraging a competition between teams drawn from industry, universities and Federal Laboratories with financial support divided approximately equally between each of the groups. The teams approach the HTS development with a broad perspective that integrates (1) basic research, (2) engineering device development, and (3) systems and production issues <u>in parallel efforts</u> at the beginning of the design development cycle. This non-traditional approach should substantially reduce the

design and development cycle time for the first generation of HTS components and applications.

We believe a fourth element is also critical to SDI producibility and is termed: "Manufacturing Operations Development and Integration Laboratories" (MODIL's). The MODIL's will be geographically distributed Centers that offer U.S. industry sustained (~5 years) R&D support. This approach minimizes duplicative and sub-critical research efforts and obviates the need for many individual, expensive research capabilities. We believe the MODIL's should compliment HTS Centers being considered for more fundamental research by other Federal organizations and could be models for accelerated process development for commercialization. The MODIL's should encourage the participation of large sectors of the committed U.S. industrial and academic technical community so they can focus their efforts most constructively.

An example best illustrates this approach. For Materials Engineers to proceed rapidly in the development of these scientifically complex materials, access to scientific expertise and sophisticated instrumentation is required. Unfortunately, these qualities are only found in a few university, Federal and large industrial Laboratories. The SDIO is supporting research in some of these Laboratories to fill SDI needs, and in a number of cases other Federal organizations are jointly supporting the required research. The intent of this approach is to provide a cost effective

means to effectively disseminate HTS knowledge that can be utilized in the U.S. by both large industrial concerns and small businesses.

SDIO has initiated a technology transfer data base describing the technology developments of each research and development effort. This information is available to qualified U.S. companies through a transfer identifier request procedure. All funded HTS research and development efforts will be included in the data base.

Although the SDI HTS program is producing many accomplishments, there are several impediments to our being able to use our national assets most effectively for HTS. We need to stabilize the Federal HTS budget and establish a streamlined contracting process for "national priority programs."

To assure success, excellence, and dominance in the area of HTS, a stable, long-term R&D program is essential. Uncertainties in Federal budgets cause enormous inefficiencies and delays in teaming arrangements, contracts, and research programs. These uncertainties are very detrimental to the morale of innovative talent in our scientific and engineering communities.

Longer term funding for MODIL's is imperative to allow key scientific talent to focus their technical skills in the most effective manner. It is essential that decision makers realize and appreciate that even though major benefits may accrue in the near term, the core U.S. program should be planned for the long term, which will yield the most significant return on our investment.

Other DoD components are showing enthusiastic cooperation in supporting the development of SDI HTS applications. They are motivated by the fact that (1) SDI is providing core funding for the development of our hardware, (2) our objectives parallel those of other DoD components, (3) the TIWG's provide a positive, dynamic, networking environment for coordination for much of the HTS work supported by the government.

The excellent cooperation among the Federal organizations has extended beyond the DoD. Through the Committee on Materials (COMAT) in the Office of Science and Technology Policy (OSTP), effective coordination and rapid communications have been established between all of the Federal organizations. In the current budget constrained environment none of the Federal organizations have sufficient funding to adequately support the HTS research and development required for a preeminent position in this technology. A unified approach, however, can provide a cost effective path to achieve excellence and a leadership position in this field.

SDI believes that HTS technologies and devices will provide a major impact on future SDI and DoD systems. With careful planning and sustained budgets, these technologies can be developed rapidly in a cost effective approach using the combined expertise of the Federal Government, private industry, universities, and the Federal Laboratories.

PANEL 1 DISCUSSION

Mrs. LLOYD. Thank you very much. Both of you have provided excellent testimony, and I would like for you, of course, to submit additional remarks you would like to make for the record. Of course, our recorder has recorded your statements this morning.

As you said, Dr. Fields, we will have to wait and see about the freeze, but let's talk about where we are right now with the freeze.

Dr. Fields said that we needed stable funding, and frozen funding could not be identified as stable funding. What has been the effect of the freeze on the morale of the people you work with, Dr. Judd?

Dr. JUDD. Well, I think the freeze has really not hit SDI that much. As you know, we're exempt from the freeze. General Abrahamson has been honoring it, however, nevertheless. We are, however, about to issue 11 contracts. The freeze could have a significant impact on that.

Mrs. LLOYD. Would it have an impact on—well, a freeze is indicative of a level of unpredictability—right? How does this affect people that you want to enter into the program?

Dr. JUDD. Well, I was just talking with some of our university researchers last weekend, and, again, they're very nervous about dealing with the Defense Department for that reason, the uncertainty of the funding. They will certainly move forward within the confines of the funding that we can give them, but I'll only remind you that in universities they make commitments to graduate students for three and four years. They simply have a very difficult time operating with funding levels that fluctuate on the levels that we're used to in other areas of advance, particularly SDIO.

Mrs. LLOYD. I appreciate that information.

You know, as both of you were speaking it seemed to me that we have a level of very excellent coordination. It seems to me that this is indicative that legislation of interagency efforts is really not needed at this time. Would you like to comment on that?

Dr. FIELDS. I feel that, in fact, it's not needed at this time. The volunteer coordination is the best kind because it isn't imposed by anyone above. I don't know of any cases where there's any duplication of effort as a consequence of ignorance of what's going on elsewhere, nor are there any gaps that I know of that are due to one group thinking another is doing it and that group thinks the first is doing it, and so on. There are definitely gaps, but that is a separate issue entirely.

So while I don't think there would be any particular harm from new legislation setting up new mechanisms for coordination and thus would not veto the idea out of hand, I also don't think that there would be a very large gain from doing so.

Mrs. LLOYD. Of course, the goal of this Committee is for the program to move forward as rapidly as possible and as soon as possible to transfer as much technology to the marketplace as we can. From that standpoint, would legislation help or not make a difference?

Dr. FIELDS. Legislation for coordination would not make any difference, particularly in speeding up that process. That's limited by issues that you've heard earlier, namely, just the general level of national support, the stability of national support, and contracting issues.

I would like to make some comments on your first question, however, because DARPA is in a different position vis-á-vis the contracting cycle than SDI, and thus the effect on us of the freeze has been considerably greater than it has been on SDI.

Mrs. LLOYD. That's what I want to know, what has happened to this point with the freeze and your programs.

Dr. FIELDS. The fact is that companies, small companies, that may have been trying to hire someone find that they can't; that person then goes away and goes somewhere else. In other cases, small companies can't sustain a team; that team is dissolved and goes elsewhere; it's not so easy to reassemble them again.

We don't know exactly what's going to happen, as I indicated earlier, but in going down our records we find that by July 1st about a third of the efforts which are now going on this early start basis will have run out of funds, and I don't know what's going to happen to them at that point. Many of them don't seek to increase their risk by further investment. I can understand that. By August 1st it will be up to a half and by September 1st up to two-thirds, so we really need to do something about this.

Mrs. LLOYD. I appreciate that.

Much of the work that you are doing is unclassified and the results are public domain. What steps are we realiy taking to ensure that the key results are available to our United States industries before they are disseminated outside of this country?

Dr. FIELDS. Well, while it's absolutely true that——

Mrs. LLOYD. This is one of our last frontiers.

Dr. FIELDS. It's absolutely true that the results in our program are unclassified. Some are in the public domain. It depends on the particular contract that we've written because, as I indicated, we try to give property rights to the companies to motivate them, to the extent that's possible. As such, these companies have the proprietary information now; they have it as soon as they generate it; they can get it into product as quickly as possible. There's no question that it will leak out, so it's a lead time issue.

By operating this way, I foresee a one- to two-year lead where otherwise you might have no lead, you might even have a lag, and that's critical, because in a fast moving field, you know, a one- or two-year lead is the difference between market success and market failure. I think that situation is well in hand for our program, which is mostly industry based.

Mrs. LLOYD. What I really want to ask both of you: Are there any impediments to technology transfer through the private sector that we can address, that need to be addressed?

Dr. JUDD. I think in SDI, of course, at some point some of our technologies will probably get into the classified domain. Let me make the distinction between basic research and technology development. Basic research is, I think, contrary to our interests to classify that, and, in fact, we certainly want to make use of and integrate the Japanese and all of the international editors as much as we can in the SDIO program. So from that standpoint, we want to gain as much from their technology as we can.

But at some point, at least in SDIO, performance characteristics, developments in performance characteristics, are very specialized technologies, will probably be in a classified area. However, that

leaves still an awful lot of things that can be transferred to the private sector, and that's worked in other parts of SDIO, and I don't envision any differences here.

Mrs. LLOYD. Thank you very much.

Mr. Morrison.

Mr. MORRISON. Thank you, Madam Chairman.

I'm interested, since one of the jurisdictions of this Committee is in the area of patents, royalties, that arrangement, and, Dr. Fields, you seem to have some kind words for the flexibility that you sense that existed out there, and I just wanted to follow up on that to see if there is any more detail on whether we really have achieved the proper balance of encouraging private enterprise, encouraging that mind at work in that laboratory even though the taxpayer is footing the bill to inspire creativity. Could we do more in this area, or have we struck that proper balance?

Dr. FIELDS. From my point of view, we in fact have struck a good balance. The key event was a change in DOD acquisition regulations, I think in 1986, but I'm not an expert in this area so I might be off by a year, which made it possible for us to give contracts to firms to develop technology and also give them patent rights to that technology as a matter of option on the part of the contracting officer. That made a tremendous difference in the willingness of companies, in my experience, to be prepared to invest in joint funding with the Department and then to invest by themselves to get products to market.

Previously, there were many cases I knew of where there were good ideas in companies that were either not getting funded adequately or not getting funded by the company because they were high risk, and yet they didn't really seek DOD funding which would tie up some of their best people because afterwards they wouldn't have anything that was unique. So that made a big difference, and I think things are going quite well at this point in time.

I submitted for the record a year ago the status at that time, which is the same as today, of what DOD's policy and procedures are for doing this, and I'd be pleased to find that again and update it, if you'd like.

Mr. MORRISON. Thank you. That would be helpful.

Dr. Judd.

Dr. JUDD. Again, in SDIO we do have this technology transfer program in place. It is a program where many small businesses and larger businesses have come in and taken SDIO technology and taken it out and developed it. It seems to be working fine now. We would simply add the HTS work to that.

Mr. MORRISON. So neither one of you really advocate any change at this point. You have some new tools, and you're applying them.

Dr. JUDD. In both the areas of Government cooperation, expediting things, and the way the system seems to be working at this point, I don't think that legislation is required to make it work; it's working now.

Mr. MORRISON. Dr. Judd, Dr. Fields indicated that all of his programs at this time were dual purpose. What percentage of SDIO programs are dual purpose, that is, you could immediately see a commercial application as well as an application in defense?

Dr. JUDD. I would say that what we would certainly focus on in SDIO is to try to identify the areas where we can use it in the SDI work itself, but in doing this all kinds of other applications come to mind, and that's why we've set up the teaming arrangements as we have, so that we can identify not only the defense applications but the applications for the commercial sector and get those out into the tech transfer as fast as we can.

Mr. MORRISON. Is it fair to say that virtually everything then that you're working on developing does have commercial applications, or commercial implications at least?

Dr. JUDD. It's hard to project ten years ahead, or five years ahead, which is what I think we're doing here, but I think it's safe to say that your answer is yes to your question, but we've certainly seen that in other programs. There's no reason to expect it wouldn't be true here.

Mr. MORRISON. Some of us that have been voting for you need that kind of defense at times. I'm particularly interested in a program, the Superconducting Magnetic Energy Storage System, which I see is a perfect example.

Dr. JUDD. That certainly is a very good example, and we are developing it for some of our specific needs, but electrical power is the same no matter whether you plug an SDI system into it or use it for load leveling on a power grid.

Mr. MORRISON. Good. Thank you very much.

Mrs. LLOYD. Thank you, Mr. Morrison.

Mr. Fawell.

Mr. FAWELL. Thank you, Madam Chairman.

Dr. Judd, you made references to the global economy in the competitive era which we're in, and, in fact, our previous questions have also centered on this, but you had mentioned that our main competitor—let me go back a little bit—that we're putting together our program and recognizing the international aspect of it and looking at Japan as the main competitor, and then emphasizing that Japan is coordinating, has a seven- to ten-year funding, and is also involved in marketing cycles, and you indicated that you felt that you were also pursuing that.

Now we hear a lot of rumors here in Congress, too, and most of it is unfounded and so forth, but quite a lot of feeling has been expressed to me, and, Madam Chairman, I think you indicated perhaps to the opposite but that there is a lack of coordination insofar as superconductivity, at least, is concerned, and that we're not doing the coordinating we ought to be doing, and one agency perhaps isn't aware of what's going on. But you're of the opposite opinion?

Dr. JUDD. I have gone through and asked our people within the organization that very question. I didn't find anything to indicate that that was the case. In fact, I found just the opposite.

Mr. FAWELL. What do you base that opinion on that there is the coordination taking place?

Dr. JUDD. The fact that meetings occurred frequently between the various Government agencies. Look at HTS applications.

Mr. FAWELL. Can you give me examples of those?

Dr. JUDD. I can—perhaps the best thing to do, if you want specific examples, I'll rely on my program manager; Dr. Northrop can perhaps give you several.

Dr. NORTHROP. I think one of the best examples in this area is the fact that I've got telephone numbers of all of the principal points of contacts in all the agencies right on my desk, and those telephone calls are moving across daily. This area is moving so fast that we couldn't rely on some sort of artificial organization structure, so the fact that the people are coordinating, we're tying our programs together, we're looking at how they can complement each other, it's happening in a way that is, I think, unprecedented in the United States right now.

Mr. FAWELL. Do you feel that the various Federal labs and universities that are involved here in all aspects of the Federal Government, they do, each other, they know what's going on and coordinating so that there's a least amount of duplication?

Dr. NORTHROP. I think the people that are at the forefront are very well coordinated. I think there is a substantial amount of efforts that are subcritical, and I think that should be—that's of concern to us, but in order to compete, I think we're going to have to draw on our best people, our strengths, and try to help focus those people on the high pay-off areas, and that's occurring.

How to accelerate the rest of the talent that wants to participate in this area is an issue that could be addressed later.

Mr. FAWELL. The private entities are also where a great deal of leadership in this field is, of course. You feel as though there is coordination there also. Certainly Japan is supposed to be the tops in reference to coordinating everybody together, and indeed it fits in, I think, with the culture of the Japanese to coordinate and cooperate and so forth. That may not be the greatest of our American many fine traits, the ability to move together, especially in free enterprise. It's not something that I think is necessarily customary. So I think it would be a difficult project to keep a high level of coordination taking place.

Dr. JUDD. I think perhaps that, commenting on that, in terms of absolutes, we may not be doing it as well as we need to be, but we're stressing to improve it. But on a relative level, compared to the way we normally do business, the way we're doing business in this one, it's going very well.

Mr. FAWELL. It's tough, I would think, and you're going against the current just because of the American culture perhaps, and also the culture of Congress. You talk about seven- to ten-year funding in Japan. There's not a whole lot of that long-term funding here. It isn't because we don't try, and I think we all recognize certainly that is necessary, and I know Madam Chairman certainly is deeply aware of that and stresses it, but with the best of efforts it's pretty darn difficult, and I know from working with the labs, they sit there with the jitters each year. They don't know where they're going to be next necessarily. So there we must be behind the Japanese, I suppose, in that area.

Dr. JUDD. I set that up as an example of what we need to do or at least a goal to obtain.

Mr. FAWELL. We certainly ain't doing it, I guess.

Dr. JUDD. But when we have to change efforts two or three times within a year, it gets to be very difficult, particularly for the academic community, not to mention the Federal house, private industries.

Mr. FAWELL. Just one other question. You also mentioned marketing cycles, that Japanese are involved in that. Is either of your entities really involved in marketing cycles?

Dr. JUDD. When I said "marketing," I really meant identification of where the technologies that you thought were going to impact.

Mr. FAWELL. Commercially as well?

Dr. JUDD. Pardon?

Mr. FAWELL. Commercially as well as governmental?

Dr. JUDD. In that respect also, because the example was given of the Magnetic Energy Storage. Although we identified that as an important technology for SDI, it also clearly has some major implications in the commercial sector. Whether it will be the most important one, it's hard to predict, but we try the best we can to see which of these technologies can be sorted out and put out the quickest.

Mr. FAWELL. Fine. Thank you.

Mrs. LLOYD. Thank you very much, Mr. Fawell.

Mr. Kanjorski.

Mr. KANJORSKI. I have no questions.

Mrs. LLOYD. Thank you, gentlemen.

I do have one question for Dr. Fields.

I want to know how much of your funding in high-temperature superconductivity in 1988 went to basic research and how much went to applications.

Dr. FIELDS. Almost none of it went to basic research. I would rather not say the rest went to applications because of this uncertainty about what's an application, but we really are not in the basic research business in high-temperature superconductivity; we're relying on other organizations to do that work.

Mrs. LLOYD. Could you give me a figure? Would you supply it for the record?

Dr. FIELDS. Perhaps 10 percent, a million or two million dollars, something like that.

Mrs. LLOYD. Thank you very much. Your testimony has been excellent, and thank you very much for being here.

PANEL 2: U.S. DEPARTMENT OF ENERGY NATIONAL LABORATORY DIRECTORS

Next we have witnesses from the Department of Energy laboratories: Dr. Alex Zucker, the Acting Director of Oak Ridge National Laboratory; Dr. Schriesheim, Director of Argonne National Laboratory; Dr. Hecker, the Director of Los Alamos National Laboratory.

Gentlemen, it's certainly nice to see you again, to take time from your very busy schedules to be here.

Dr. Zucker, if you will lead off, your entire statement will be made a part of the record. You gentlemen may summarize or proceed as you wish, and your entire statements will appear in the record. Thank you very much for being here.

Alex.

STATEMENT OF DR. ALEXANDER ZUCKER, ACTING DIRECTOR, OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TN

Dr. ZUCKER. Thank you very much, Madam Chairman.

The field of high-temperature superconductivity is an exciting area of research and an important area for technological development. A central feature of the laboratory superconductor R&D program is the study of the mechanisms that limit the current-carrying capacity of these materials. For most practical applications of superconductors, the capacity of a million amperes per square centimeter is needed, about 100 times higher than the best currently obtained for bulk forms of high-temperature superconductors.

We demonstrate in our research that there is a thin layer at grain boundaries with a different composition from the balance of the superconductor material. This layer likely has a detrimental effect on the current-carrying capacity of the material, and we are now studying what impact compositional variations and processing techniques have on both the grain boundary layer and the current-carrying capacity of these materials.

Neutron scattering has played a uniquely important role in deciphering the mechanisms for superconductivity in these materials because of its sensitivity to the structure and the magnetic behavior of the atoms. Recent results from experiments conducted by ORNL staff at Grenoble have provided detailed information on the structure of the new thallium superconductor.

Unfortunately, since the discovery of the new superconducting materials, the scientific community has been without the use of the highest flux research reactor in the United States, the High Flux Isotope Reactor at ORNL. The HFIR is scheduled to resume operation in August of this year, which should be a great boon to the neutron scattering community and for the characterization of superconducting materials.

Scientists at Oak Ridge routinely produce superconductor films by a number of techniques. Thin films have important potential applications in electronic circuits and as superconducting coatings. Thin films with thicknesses of half a millimeter have been produced by evaporation that have current carrying capacities larger than 50,000 amperes per square centimeter.

Thin superconductor films with thicknesses from a few angstroms to several micrometers have been produced by pulsed laser ablation. We were the first laboratory to define the conditions required for stoichiometric production of thin films with ablation techniques. We believe this technology is capable of depositing superconducting coatings of low temperatures that will be suitable for conducting tapes and thin film sensors.

ORNL is also responsible for studies in technology areas, especially those for motors, separating systems, power electronics, and materials fabrication. There we have input from over 25 major industrial concerns, including Allied Signal, American Magnetics, AT&T, Emerson—Emerson Electric, IBM, Intermagnetics, et cetera. Some of these people will be testifying here this morning a little later.

We have designed a motor which will use superconducting materials that are currently available to test the concepts, and we

expect that a, say, 175-horsepower superconductor motor will weigh about 125 pounds while the same size of a conventional motor weighs about 1,500. So we are dealing with very substantial reductions in weight of motors.

I'd like to at this point turn to technology transfer, Madam Chairman. In the area of technology transfer, ORNL has much to offer American industry. In the area of superconductors, our chemists are working on new methods for bulk production of ceramic powders. Scientists at the Surface Modification and Characterization Facility are studying the fundamentals of thin film production.

Microwave sintering, a process under development at ORNL for sintering of ceramic materials, promises improved processing of superconductors at lower temperatures, shorter times, and with the reduced possibility of contamination. The High Temperature Material Laboratory is unsurpassed in its capabilities for characterization of ceramics, including the high-temperature superconductors. Our powder characterization facilities offer real opportunities to industry for the study of fabrication processes used to produce powders.

In my testimony to you last March, Madam Chairman, I proposed that the National Laboratories serve as a technological commons, freely accessible institutions and facilities to serve American industry in its quest to regain leadership in global commerce. Things are developing more rapidly than even I had expected a few months ago. The High Temperature Materials Laboratory now has 12 industrial projects, up from 6 only last March, with industrial inquiries arriving at the HTML essentially daily.

Through its existing user facilities and the evolving Superconductivity Pilot Center, ORNL is already a commons for superconductivity research and development and is striving to improve industrial interactions.

The Superconductivity Pilot Centers warrant some comments at this point. This is a daring and forward-looking initiative by the Department of Energy that we feel will play a pivotal role in our future ability to interact effectively with industry. ORNL has been most effective in transferring our technology to industry, as witness the May 13 *Science* article which is entitled "Labs Struggle to Promote Spin-Offs: Oak Ridge Leads the Way." I have appended that for the record; we are proud of that.

Mrs. LLOYD. I was going to refer to that at the close of your testimony. I'm very proud. There are some things in there I'm not proud of, but I'm proud of what we are doing. But certainly it's not your fault we're not doing better.

Dr. ZUCKER. I'll come to that. The part that we're not doing well, I'll come to that a little later. However, these interactions are often slow and cumbersome because of all the legal requirements associated with the transfer of intellectual property developed with Government funds under contract with private industry.

The Superconductivity Pilot Centers have been established as pilot projects to streamline precisely this business of legal interface between Government and industry. We agree with DOE that there should be stronger local authority in the approval of agreements

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with industry and that existing policy procedures must be streamlined and modified to encourage private sector participation.

The three National Laboratories have been asked to form Superconductivity Pilot Centers at Oak Ridge, Argonne, and Los Alamos. These laboratories have established a steering group, have had several separate and combined organizational meetings, and have met together with local operations offices to formulate management plans and much faster routes for technology transfer.

An important point that needs to be examined relates to intellectual property which remains under discussion between DOE and the pilot centers. This issue is currently being discussed, and I hope that within the framework of cooperation fostered by the Pilot Centers a mutually satisfactory agreement will be reached.

Each laboratory plans to structure its Pilot Center to maximize successful interactions with industry, but each will organize around the strengths of its individual programs. Since the funding anticipated for the Pilot Centers will not be sufficient to mount significant technological thrusts unassisted, the approach planned at ORNL Center will be to leverage these funds through, one, close coordination with existing programs in superconductivity; utilization of existing ORNL user facilities; and cost sharing with industry. The Pilot Center funds will be used to extend existing ORNL R&D programs into products or new technologies through cooperative projects with industry, to implement new ideas which arise from ORNL-industry interactions, and to accelerate the transfer of new superconductor technologies to U.S. industries.

We view the Superconductivity Pilot Center initiative with great enthusiasm. Nevertheless, there are several cautions that should be voiced. First, high-transition-temperature superconductivity is an emerging technology. We still do not understand the basic mechanisms, and there are many materials and processing problems to be overcome before large-scale commercialization is possible. Second, the level of funding for these programs is small. Consequently, significant success will only come through coordination of resources, such as we propose. Finally, we should be reminded that an important goal of this initiative is to find solutions to the business and legal impediments that prevent U.S. industry from having maximum beneficial access to R&D at the National Laboratories.

Thank you, Madam Chairman.

[The prepared statement of Dr. Zucker follows:]

Alexander Zucker

Acting Director

Oak Ridge National Laboratory

Testimony Before the

Subcommittee on Energy Research and Development

Committee on Science, Space, and Technology

June 23, 1988

TESTIMONY

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

June 23, 1988

Good Morning. My name is Alexander Zucker. I am the Acting Director of the Oak Ridge National Laboratory. I appreciate the opportunity to testify before the Subcommittee on Energy Research and Development. The field of high temperature superconductivity is an exciting area of research and an important area for technological developments. In your letter inviting me to testify, you asked that I address several points relating to our technology transfer and high temperature superconductor research program. I will first discuss recent advances in our research and development program. The balance of my testimony will address our technology transfer program, including the status of the DOE Superconductivity Pilot Center at ORNL.

A central feature of our superconductor R&D program is the study of the mechanisms that limit the current carrying capacity of these materials. For most practical applications of superconductors, a capacity of a million amperes/cm^2 is needed - about 100 times higher than the best currently obtained for bulk forms of the high temperature superconductors. We are approaching this problem from a number of directions. The superconductor materials are being characterized with a number of techniques. Auger Microscopy and Atom Probe Field Ion Microscopy have demonstrated that there is a thin layer at grain boundaries with a different composition from the balance of the superconductor material. This layer likely has a detrimental effect on the current carrying

capacity of the material. We are now studying what impact compositional variations and processing techniques have on both the grain boundary layer and the current carrying capacity of the materials.

Control of grain orientation may also lead to an increase in the current carrying capacity. ORNL is developing techniques for processing powders in a composite form in a magnetic field to study this effect. While this investigation is in its early stages, preliminary results are promising.

Neutron scattering has played a uniquely important role in deciphering the mechanisms for superconductivity in these new materials because of its sensitivity to the structure and magnetic behavior of the atoms. Recent results from experiments conducted by ORNL staff at Grenoble have provided detailed information on the structure of the new Thallium superconductor ($Tl_2Ca_1Ba_2Cu_2O_8$). The results indicate that the superstructure is quite different from that found in the Bismuth superconductor ($Bi_2Sr_1Ca_2Cu_2O_8$). Other neutron results indicate that the valence state of the copper in the superconductor materials is different than that calculated with band structure models. During much of the time since discovery of the new superconducting materials, the scientific community has been without the use of the highest flux research reactor in the U.S., the High Flux Isotope Reactor (HFIR) at ORNL. The HFIR is scheduled to resume operation in August 1988, and should be a great boon to the neutron scattering community and the characterization of superconducting materials.

Diagrams demonstrating the variations in materials as a function of composition and important heat treatment conditions are essential in all realms of materials. For the high temperature superconductors, these diagrams are complex due to the number of elements making up the material. ORNL has made significant progress in defining this basic information for the Bismuth superconductors.

Scientists at ORNL can routinely produce thin superconductor films by a number of techniques. Thin films have important potential applications in electronic circuits and as superconducting coatings. Thin films with thicknesses of 0.5 mm have been produced by evaporation that have current carrying capacities greater than 50,000 amperes/cm^2 at liquid nitrogen temperatures. At present, the current measurements are limited by the contact resistance between the superconductor and the wires used for the measurement, not by the superconductor. However, characterization of much thinner evaporated films with ion backscattering and high resolution scanning transmission electron microscopy has demonstrated that the films interact with the substrate, resulting in lattice parameter variations with orientation and in poor superconducting properties. The growth characteristics and substrate dependence are the focus of more detailed investigations.

Thin superconductor films with thicknesses from a few angstroms to several micrometers have been produced by pulsed laser ablation. We were the first Laboratory to define the conditions required for stoichiometric production of thin films with the ablation techniques. Our physicists are currently studying the laser-induced plasma to better understand the fundamental processes. New

techniques for laser ablation that utilize multiple sources are being developed. We believe this technology is capable of depositing superconducting coatings at low temperatures that will be suitable for conducting tapes and thin film sensors.

Additional efforts are in progress to evaluate molecular beam epitaxy and other thin film growth techniques for superconductor materials. ORNL scientists have developed and proven a high temperature fusion cell for molecular beam epitaxy capable of operation at 2,000 degrees Celsius that makes ~~disposition~~ deposition of superconducting films possible with this technique.

We are also studying potential applications of this new technology for energy utilization and conservation under a joint DOE/EPRI assessment being conducted by the DOE National Laboratories with industrial input. ORNL is responsible for the overall coordination of the assessments and studies in the technology areas of motors, separating systems, power electronics, and materials fabrication. ORNL has received input in our studies from over 25 major industrial concerns including Allied Signal, American Magnetics, AT&T, Bell, Emerson Electric, IBM, Intermagnetics General, J. M. Huber, and Westinghouse. The final report will be completed in October 1988. Innovative concepts and designs utilizing the unique properties of the high temperature superconductors are resulting from these assessments. For example, our engineers have designed a superconductor variable speed, constant torque motor. The use of superconductor windings will increase the torque, and consequently the horsepower, by more than an order of magnitude above that

achieved by a comparable size permanent magnet motor. For example, a 175 hp superconductor motor is expected to weigh 125 pounds while a 175 hp conventional motor weighs 1,500 pounds. The superconductor motor design has the advantage that it can be demonstrated with current superconductor material, with the potential of using the new high temperature superconductor materials in the future.

TECHNOLOGY TRANSFER

In the area of technology transfer, ORNL has much to offer American Industry. Our chemists are working on new methods for bulk production of the powders that will enable industries to select appropriate and new optimized processes for their use in the production of the high temperature superconductors. Scientists at the Surface Modification and Characterization Facility are studying the fundamentals of thin film production, essential for the manufacture of electronic devices. Microwave Sintering, a process under development at ORNL for sintering of ceramic materials, holds promise for improved processing of the superconductors at lower temperatures, shorter times, and with reduced possibility of contamination. Our facilities for characterization of the microstructures and properties of these materials are superb and are available to industrial users. The High Temperature Materials Laboratory (HTML) is unsurpassed in its capabilities for characterization of ceramics - including the high temperature superconductors. Our powder characterization facilities offer a real opportunity for the study of the fabrication processes used to produce

powders. The neutron scattering facilities at the HFIR, when it returns to operation in August, provide the best facilities in the U.S. for the study of these materials.

In my testimony before you last March, I proposed that the National Laboratories serve as a "technological commons"; freely accessible institutions and facilities to serve American Industry in its quest to regain leadership in global commerce. Things are developing more rapidly than even I had expected a few months ago. The High Temperature Materials Laboratory now has 12 industrial projects, up from 6 in March, with industrial inquiries about the HTML coming in on a daily basis. Through its existing User Facilities and the evolving Superconductivity Pilot Center, ORNL is already a commons for superconductivity research and development -- and is striving to improve industrial interactions. While the majority of our current superconductor research is supported by DOE, we already have significant collaborations with over 25 university personnel in our research programs. Joint research projects in numerous areas are being discussed with several industries. In addition, several non-DOE agencies have expressed interest in collaborating with activities in the Superconductivity Pilot Center.

HIGH TEMPERATURE SUPERCONDUCTIVITY PILOT CENTER AT ORNL

The Superconductivity Pilot Center program is a daring and forward looking initiative by DOE that we feel will play a pivotal role in our future ability to

interact effectively with industry. ORNL has been very effective in transferring our technology to industry, as presented in the May 13, 1988, Science magazine article, "Labs Struggle to Promote Spin-offs: Oak Ridge Leads the Way." (Appended for the record.) However, these interactions are often slow and cumbersome because of all the legal requirements associated with the transfer of intellectual property developed with government funds under contract with a private company. The Superconductivity Pilot Centers have been established as a pilot project to streamline the business and legal interface between government and industry in the transfer of technology developed in this important area. We agree with DOE that there should be stronger local authority in the approval of agreements with industry, and that existing policy procedures be streamlined and modified to encourage private sector participation and provide competitive advantages to the partners.

We also believe that additional measures to enhance the success of the Pilot Centers are possible and desirable. Although this initiative is fairly new, having been announced by Secretary of Energy Herrington in April, it is clear from initial interactions that it has stimulated new levels of cooperation and enthusiasm among the National Laboratories, the DOE, and our local field offices. The three National Laboratories asked to form Superconductivity Pilot Centers are ORNL, Argonne National Laboratory and Los Alamos National Laboratory. These Labs have established a steering group, have had several separate and combined organizational meetings, and have met together with the local operations offices to formulate management plans and much faster routes for technology transfer. In the planning stage are such items as a

common brochure and newsletter, a joint video of the three laboratories capabilities in high-temperature superconductivity, a joint industry kickoff meeting and annual information meetings, and the establishment of an electronic bulletin board for all participants.

There is one remaining point relating to intellectual property which remains under discussion between DOE and the Pilot Centers, namely the ~~deposition~~ disposition of intellectual property rights in joint industry-laboratory collaborations. This issue is currently being discussed and I am certain that, within the framework of cooperation fostered by the Pilot Centers, a mutually satisfactory agreement will be reached that will maximize the benefits to American Industries.

Each Laboratory plans to structure its Pilot Center to maximize successful interactions with industry, but each will organize around the strengths of its individual programs. Since the funding anticipated for the Pilot Centers will not be sufficient to mount a significant technological thrust unassisted, the approach planned for the ORNL Center will be to leverage these funds through: 1) close coordination with existing ORNL programs in superconductivity, 2) utilization of existing ORNL User Facilities, and 3) cost sharing with industry. The Pilot Center funds will be used to extend existing ORNL R&D programs into products or new technologies through cooperative projects with industry, to implement new ideas which arise from ORNL-industry interactions, and to accelerate the transfer of new superconductor technologies to U.S. industries.

It should be clear that ORNL views the Superconductivity Pilot Center initiative with great enthusiasm. Nevertheless, there are several cautions that should be voiced. First, high transition temperature superconductivity is an emerging technology. We still do not understand the basic mechanisms and there are many materials and processing problems to be overcome before large scale commercialization is possible. Second, the level of funding for these programs is small. Consequently, significant success will only come through coordination of resources, such as we are proposing. Finally, we should be reminded that an important goal of this initiative is to find solutions to the business and legal impediments that prevent U.S. industry from having maximum beneficial access to R&D at the National Laboratories.

Labs Struggle to Promote Spin-Offs

Federal laboratories are increasingly viewed as promising sources of commercial technology, but getting it into the private sector is proving difficult

LAWRENCE Livermore National Laboratory, best known for its work on nuclear weapons and the Strategic Defense Initiative for the Department of Energy (DOE), may seem an unlikely partner to the U.S. steel industry. Last year, however, together with North Star Steel, Caterpillar Tractor, and Ladish, a custom steel forging company near Milwaukee, the laboratory began spending $1.8 million of DOE money to develop a new type of superplastic steel. The steel can be forged in extremely precise shapes, said Jack Geiger, vice president for technology at North Star Steel, thus eliminating much of the expensive machining now required to produce steel machinery parts.

Working hand in glove with private companies on proprietary research projects is a novel experience for most scientists in the federal laboratories. But if Congress has its way, such collaboration may be the wave of the future. The federally funded laboratories are being ordered to the front in the trade wars with Japan and Western Europe.

"The Department of Energy laboratories are a huge treasure and storehouse of knowledge and science," said Senator Pete Domenici (R–NM). "My dream is that they could be one of the lead institutions adding to America's ability to apply technology to the marketplace. But their record of traceable new products spun off is so small that one would almost think they're not charged with doing it."

Congress passed several laws during the past decade encouraging laboratories to promote commercial spin-offs from their research. Until recently, however, little changed, say most observers. But the current trade crisis has spawned a political campaign for "technology transfer"—finding commercial uses for technology developed inside government laboratories—and federal research administrators are busy clearing away bureaucratic obstacles and hoping that the promised spin-offs actually appear.

By any standard, the federal laboratory network is a huge part of the U.S. R&D establishment. According to James Wyckoff of the National Bureau of Standards, more than 400 federally funded labs spend about $20 billion each year on in-house R&D. The Defense Department, the Department of Energy, and NASA account for 84% of that total, with a variety of other agencies, including the departments of Health and Human Services, Commerce, and Agriculture making up the difference. Just over 100,000 scientists and engineers—one-sixth of the nation's active R&D professionals—work in these facilities, according to the

Senator Domenici. *"There's no question there's an endave mentality in the DOE labs."*

Federal Laboratory Consortium, a government-funded group organized to promote cooperation between private industry and the federal labs.

Reliable statistics on the extent of commercial spin-off from this research complex are impossible to compile, but most R&D experts consulted for this article agreed that little laboratory technology had found its way to the marketplace. "We're getting such a minuscule amount out of [the federal labs] that almost any improvement would be a big step in the right direction," said Lee Rivers, Washington representative for the Federal Laboratory Consortium.

"The public is being ripped off; it isn't getting its money's worth from federal research, because there aren't good mechanisms of technology transfer," said Roger Ditzel, director of the University of California Patent Office. Ditzel is responsible for the rights to technology from the Lawrence Livermore, Lawrence Berkeley, and Los Alamos National laboratories. His office examines 20 to 30 inventions a year from these three laboratories, sometimes negotiating agreements with companies that want to develop commercial products using the inventions.

Partnerships between labs and industry often sound better in theory than they work out in practice. Four years after White House Science Adviser George Keyworth called on the national laboratories to "develop leapfrog technologies in steelmaking," Lawrence Livermore's research into superplastic steel production is the only R&D work currently funded by the "Steel Initiative." According to one DOE official familiar with the program, joint projects that represent common ground between the laboratories' "research culture" and industry's "production culture" have been hard to find.

Most of the research carried out in government labs, such as classified work on military technology or very basic science, is commercially irrelevant. Alex Zucker, acting director of Oak Ridge National Laboratory, estimated that from 10 to 30% of the research in DOE's nonweapons laboratories—and a smaller percentage in weapons labs such as Lawrence Livermore—involved technology that could be commercially useful. But according to advocates of laboratory-industry collaboration, even when the labs do develop technology that may have commercial uses, it often languishes on the shelf because government regulations and the research culture of the lab discourage private companies from developing it further.

The main obstacle, say corporate executives and spin-off advocates, has been government reluctance to sign contracts that give a single company exclusive rights to a particular technology, and therefore a marketplace advantage. Without this incentive, they say, no firm will invest the large sums of money that are necessary to turn laboratory technology into a commercial product.

In Lawrence Livermore's cooperative research with the steel industry, for example, only the three private companies participating in the project—none of which directly compete with each other—will have immediate royalty-free access to the technology if the research yields practical results, giving them a leg up on their American and foreign rivals. "If there'd been a competitor in it, we

wouldn't be here," said one corporate executive involved in the project.

Traditionally, the government felt that "if the public pays for anything, then it ought to be free to anyone," said Ditzel. Any information or patent rights the government made available to one company had to be provided to everyone else on the same terms. But because few companies saw much value in investing in laboratory technology on these terms, they preferred to pursue their own separate R&D programs. "One thing on which industry is unanimous is that what's available to everybody is worthless," said Zucker.

To get over this hurdle, Congress passed a series of laws from 1980 to 1986 pressuring federal agencies to give each laboratory the authority to license technology to individual firms. As an added incentive to promote spin-offs, the laws allow inventors and laboratories to keep a substantial percentage of any royalties paid on these licenses.

Many agencies have been slow to put the laws into effect. None of the military services, which together control the largest federal laboratory system, have approved final regulations explaining how the law will be implemented, although a few cooperative research agreements have been arranged. The Department of Energy, meanwhile, has refused to give the contractors that operate many of its laboratories a blanket authorization to negotiate licenses for their unclassified technology. Instead, the laboratories must ask DOE headquarters to waive its prior rights to the inventions, a process that often takes more than a year.

The lack of a coherent framework for granting licenses is not the only impediment to transferring technology out of the national labs. Laboratory directors remain concerned about the possibility of releasing classified technology, getting caught in the middle of competitive battles between private firms, and compromising the laboratory's central mission.

"It represents caution on both sides," said Joe La Grone, manager of DOE's Oak Ridge operations. "The thing that makes technology transfer go slowly is making sure we don't open the gate and let tremendous resources flow out and allow advantage to one or a very few people."

Negotiating terms for licenses that will promote commercial developments "is very much of an art," said Ditzel. "You've got to know what you're doing. It takes a lot of years to know what to look for." A lack of government patent lawyers with experience

Oak Ridge Leads the Way

Oak Ridge, Tennessee

Despite the obstacles in moving technology out of the federal labs and into the private sector, the Department of Energy's Oak Ridge National Laboratory (ORNL), operated by Martin Marietta Energy Systems, has become something of a showpiece for technology transfer during the past 3 years. Martin Marietta made local economic development and the promotion of spin-offs a centerpiece of its successful proposal when it bid on the contract to operate DOE's Oak Ridge facilities in 1983, and has taken pains to deliver on its promises.

"We wanted to become the community's favorite bidder," said Bill Carpenter, the Oak Ridge corporation's ebullient vice president for technology application. Carpenter is responsible for promoting commercialization of technology at three DOE facilities at Oak Ridge: ORNL, a nuclear weapons production facility called Y-12, and a uranium enrichment plant. ORNL's operating budget this year is $456 million, Y-12's is $509 million, and the enrichment plant's is $102 million. Together, the Oak Ridge facilities employ 15,000 people.

"We didn't know what the reservoir of technology was worth, but we said, gosh, 1000 Ph.D.'s have got to be doing some worthwhile things," said Carpenter, who moved to Oak Ridge in 1983 from Martin Marietta's plant in Orlando, Florida. "We knew something about the complexity of someone adopting a technology they didn't originate, because we have a hell of a time right within our own corporation when we shift from development to production—it's one of the toughest problems we have," he said.

Carpenter set up an Office of Technology Applications to promote commercial licensing of ORNL technology. Twenty-seven license agreements have since been signed. Four of them have produced results so far—a total of $10 million in sales and $400,000 in royalties for ORNL.

ORNL's most extensive cooperative research agreement with industry centers on a remote-controlled robot that was originally developed at a cost of well over $1 million to carry out maintenance in contaminated areas of nuclear fuel reprocessing plants—none of which are now planned in the United States. ORNL has agreed to provide the entire system to a local company called Remotec in exchange for Remotec's help in developing a commercial version of the robot. ORNL will then get one of the commercial devices free of charge.

Private companies have been most interested in the laboratory's advanced materials, including new metal alloys and ceramics. ORNL's two hottest commercial spin-offs at the moment are a form of nickel aluminide that keeps its strength at extremely high temperatures, making it useful in engine parts or heating elements, and a reinforced ceramic material that promises 25-fold improvement in the durability of cutting tools.

By 1992, ORNL hopes to negotiate 50 licenses a year, generating $4 million each year in royalties from $100 million in commercial sales based on laboratory technology. "We've only just begun," said Jon Soderstrom of ORNL's technology applications staff. "I don't see any plateauing of these curves soon."

Hal Schmidt, a former ORNL physicist who helped start two companies based on spin-off technology, said that researchers at ORNL who want to work with private companies now face a completely new set of attitudes. "Twenty years ago, any involvement with industry was considered unethical," said Schmidt. "Now, it is enormously encouraged."

Once the question of who gets what rights is settled, it is crucial to have federal researchers working side by side with company engineers to develop commercial products, said several experts. "If you want to transfer technology, you have to transfer technologists," said one steel industry source. For this reason, Martin Marietta Energy Systems began encouraging ORNL scientists to work as consultants with industry on their own time. The number of consulting agreements reported by ORNL employees shot up from 71 in 1985 to 190 in 1987.

But despite the bullish trends at ORNL, the flow of technology from federal laboratories to private companies remains a mere trickle, and its potential for growth remains uncertain. "If you look at 27 licenses in comparison with all that's out there, its not a staggering number," said Joe La Grone, manager of DOE's Oak Ridge operations. ■ D.C.

in licensing, said Dittel, has compounded the problem.

According to Don Jarad of Oak Ridge's technology transfer staff, the laboratory sometimes has to choose which companies will get rights to Oak Ridge's technology. "The name of the game is success," said Jarad. "We select them on the basis of who we think will be a success." Oak Ridge, in fact, has been particularly aggressive in transferring its technology to the private sector (see box).

Rivers of the Federal Laboratory Consortium says "the battle will go to the more aggressive, and the first one in the door." At least one firm has threatened to sue Martin Marietta, which operates Oak Ridge, over a license that was not granted, but so far no suits have been filed.

Laboratory administrators walk a fine line in promoting commercial spin-offs, yet keeping research within bounds of the laboratory's mission. "You're not going to allow a researcher to go off and work with some company if that's going to detract from the overall mission of the lab," said Dittel. Supporters of the technology transfer effort, however, maintain that cooperation with industry is far from any danger of interfering with ongoing research. "I'll be retired by the time technology transfer starts seriously impeding defense work," laughed one DOE weapons laboratory official.

According to officials at a DOE nuclear weapons laboratory, a proposal now circulating within DOE headquarters would open the doors of the weapons labs to far more extensive cooperation with industry. Details of the proposal remain to be worked out, said one official familiar with it, but it would represent a sharp turn in DOE policy toward the weapons labs.

The lab official said that promoting commercial spin-off might reinforce political support for the labs in Congress. Arms control success "doesn't bode well for continued funding of DOE weapons labs," he said. "But our national security has to be tied to our economic competitiveness," and the labs could contribute to that goal.

According to the weapons lab official, greater cooperation with industry need not compromise national security controls over technology. In fact, he said, commercialization might make the export control task easier. If technology was licensed to a single firm, he said, commercial secrecy during development of a product may aid in the task of restricting its export. "Computer source code licensed to a private company for resale [in machine readable form] isn't going to be freely available from Argonne National Laboratory," he said.

For many labs, however, classification remains a touchy issue. "One of the toughest things is making sure you don't cross the line into national security information," said La Grone. DOE officials say that manufacturing technology developed at the Y-12 weapons plant would be valuable for industry, but it is off limits because of classification.

No matter how faltering the progress toward formal cooperation, changing attitudes within both labs and industry contain the seeds of a bright future for collaboration, said Jon Soderstrom of Oak Ridge's technology applications staff. "People are interested, much more than before, in making people on the outside aware of their technology," said Soderstrom. "Our best leads on licensing come from our technical staff."

Contacts between industry and federal laboratories can break down the "cultural barrier" that divides government and corporate scientists and engineers, said Rivers. "Look, we send people back to school or to other federal labs, and there's an awful lot of smart researchers out in industry; our researchers can learn a heck of a lot from those people," said Dittel.

Domenici agreed. "There's no question there's an enclave mentality in the DOE labs," he said, that hinders the transfer of technology into the commercial marketplace. "They were closed institutions for a long time."

"We've tried to remove the statutory barriers, we're trying to remove the regulatory barriers, but just to change the culture, that is a people problem, and that's not easily done," said Bill Carpenter, vice president for technology application at Oak Ridge. ■

DANIEL CHARLES

Daniel Charles is a free-lance writer based in Washington, D.C.

Mrs. LLOYD. Thank you very much, Alex.
Dr. Schriesheim.

STATEMENT OF DR. ALAN SCHRIESHEIM, DIRECTOR, ARGONNE NATIONAL LABORATORY, ARGONNE, IL

Dr. SCHRIESHEIM. Madam Chairman, I, of course, have written testimony and submit it for the record, and I'll skip through, making some points, and, following the excellent testimony of Dr. Zucker, I won't cover everything in detail.

I might point out that Argonne has a total budget for high-temperature and low-temperature superconductivity that places it probably in, if not the largest, certainly one of the largest publicly supported activities in this field, some $10 million—close to $10 million, the bulk of it, of course, from DOE, and $1 million from outside DOE, chiefly an SDIO program, and we have another $2 million or so pending in different stages of negotiation, chiefly from industry.

We have been designated by President Reagan as one of the Nation's superconductivity applications centers, by the Department of Energy, as Alex has pointed out, one of these Pilot Centers for commercialization, along with Oak Ridge and Los Alamos, and we have a very aggressive tech transfer program.

What I'd like to just comment on, though, are some of the problems and opportunities in superconductivity because they're common to other areas of technology transfer. As an example, locating good candidate firms is always the first problem in any technology transfer. It's particularly difficult, though, in high-temperature superconductivity because the field is so new and the potential of it so wide.

We've attacked this in a variety of ways at Argonne, as have the other National Labs. We have an aggressive publicity effort in the media and the trade press. I participate in the outreach activity on CSAC board, as does Dr. Hecker; the boards of trade magazines; and regular speaking appearances. We're particularly proud of a telephone hotline that we established in 1987. Since the establishment of that telephone hotline, we've had over 1,500 inquiries from industry. These are small industries, medium- and large-size, and venture capitalists. It represents a very real tech transfer activity.

Because the superconductivity is ill-defined, we found that cooperative sponsorship of meetings at the Laboratory to be another very effective way of making contact.

The second problem, though, also unique to high-temperature superconductivity, is that so many companies themselves have not defined the role that they would like to play. This is true of large and sophisticated corporations as well as small, beginning companies, and part of the responsibility of the laboratory is to help them find their niche, and a third problem in dealing in this particular area is the imperfect knowledge that companies have of the Federal system and the procedures which private firms need to use in dealing with National Labs, and most companies, in our experience, tend to be of two extremes. One is the expectation that they could walk into the gate, pick up the discovery, and walk back out

with exclusive rights, and the other, of course, is the fear that they'll get completely bogged down in the Federal bureaucracy.

So another part of our job is to educate these companies and walk them through the system, and, of course, the fourth is the need for the Lab to offer a wide variety, a diversity, of options for transferring the technology, and one rigid routine simply will not do. So flexibility is the key; too many companies, too many wide varieties of operations.

So we have about ten different forms of cooperation, elaborative research, and development agreements. An example: we and Grumman Aerospace Systems—Grumman Space Systems have agreed to a study of surface microstructure and chemistry, of high-temperature superconductors and their radio-frequency properties, and this technology transfer relates directly to that SDIO program I mentioned at the beginning which is on neutral particle beams.

A second channel is for the cooperation to pay Argonne staff to do proprietary work, where we are about to sign an agreement with American Superconductor Corporation of Cambridge, Massachusetts, on sputter deposited and metal ceramic bonding of superconductors, and to show how these techniques can be used in tandem we're also close to signing a contract with American Superconductor to license an Argonne patent.

The fourth way, of course, is to work with industrial consortia, and, as Dr. Zucker pointed out, these Pilot Centers will be used as brokers to put together groups of companies with common interests, and we're working with EPRI in exactly that category.

Another option, of course, is to use a combination of Government agencies. The State of Iliinois is funding the Illinois Superconductivity Institute and cosponsored a recent Argonne conference on superconductivity. The industrial residencies and post-doctoral appointments have proved excellent. We have nine such appointments in superconductivity ranging from Dow Chemical and Allied-Signal, for example.

One innovation that we're particularly proud of is, we set up a Superconductivity Affiliates Program. We have nine corporations currently in that superconductivity program ranging from Amex and Amoco to Arco, Chevron, to Lake Shore Cryogenics and BIS Corporation—two small corporations. These companies really form the nucleus of an industrial advisory group, and we have worked with the local area in terms of SBIR work.

Finally, we have a unique option in the Argonne-University of Chicago Development Corporation, or ARCH. I know this Committee has heard about ARCH, Madam Chairman. Patents on Argonne discoveries can be waived by DOE to the University of Chicago and then to ARCH, which serves as an effective negotiator and facilitator to commercialize the discoveries.

One of the advantages of ARCH is that it cuts down on delays which corporations sometimes face in commercializing a project. As an example, the first license that ARCH cut, if you will, covered a helium dilution refrigerator developed in the laboratory. We signed that within one month after we undertook negotiations. That's an example of what we can do.

We're structuring the Pilot Center; I don't think I'll say any more on that particular issue. A couple of issues I believe that the

Committee would perhaps examine; one has to do with the issue, of course, of working and trying to work pragmatically with foreign corporations that have large affiliates in this country. How do you define which ones you work with? Tax, employment benefits, those kinds of issues.

The issue of exclusivity can be resolved perhaps through a two-tiered system where base patents are licensed on a nonexclusive basis and niche patents are licensed to companies on an exclusive basis. So the laboratories need flexibility in dealing in that particular area.

The issue that came up before of disclosure of know-how: for example, we need to deal with the Freedom of Information issue on disclosure of know-how and when the laboratories can treat information as confidential for a period of a year or two in order to give U.S. corporations an edge, and I certainly agree, again, with what Alex has said, that the creation of these Pilot Centers really is a very forward looking activity on the part of the Department, and part of the reason, I believe, to put those together is to find out what the problems are, and there will undoubtedly be some that will need to surface and then solve.

So certainly we at Argonne take super high-temperature superconductivity technology transfer and the Pilot Centers very seriously—it is a very worthwhile national effort—and intend to fulfill that obligation as best we can, with your help.

[The prepared statement of Dr. Schriesheim follows:]

TESTIMONY BY DR. ALAN SCHRIESHEIM
DIRECTOR, ARGONNE NATIONAL LABORATORY
BEFORE THE ENERGY RESEARCH AND DEVELOPMENT SUBCOMMITTEE
HOUSE COMMITTEE ON SCIENCE SPACE AND TECHNOLOGY
THURSDAY, JUNE 23, 1988

Madam Chairman and members of the Subcommittee:

I am Dr. Alan Schriesheim, Director of Argonne National Laboratory.

Argonne has the largest publicly funded research team in the U.S. at work on high temperature superconductors -- more than 100 scientists. Our annual budget for such research totals around $10 million. About $1 million is from outside DOE -- an SDIO program. We have another $2 million or so pending in various stages of negotiation -- chiefly from industry.

My laboratory has been designated by President Reagan as the nation's Superconductivity Research Center for applications; and by the Department of Energy as a pilot center to develop more effective ways to foster commercialization of the new technology. Argonne already has a very aggressive program of technology transfer covering all the activities of the laboratory.

Having offered those credentials, I would not claim to know everything necessary to transfer superconductivity discoveries to industry. No one does. We are all on a sharp learning curve.

Many of the problems and opportunities in superconductivity are common to other areas of technology transfer. But some of them are unique ... in degree, if not in kind.

For example, locating good candidate firms is always the first problem in all technology transfer. But it is particularly difficult for high temperature superconductivity because the field is so new and the potential is so wide.

We at Argonne have attacked this problem in a variety of ways. We maintain an aggressive publicity effort in both the general media and the trade press. I participate personally in the outreach effort through membership on the CSAC board, the boards of trade magazines and through regular speaking appearances at national conferences for industry.

We have established and publicized a telephone superconductivity hotline for industry. And we have organized a series of major meetings on superconductors starting with the first industry conference to be held at a national lab a year ago, and continuing with a conference for small businesses a few weeks ago.

Because the superconductor industry is ill defined, we have found cooperative sponsorship of these meetings by trade associations to be an effective way to spread a wide net for potential candidate companies.

A second problem is also unique to high temperature superconductivity in terms of its pervasiveness. It is that so many companies have not defined the role that they can best play. This is true of large and sophisticated corporations as well as small beginning firms. Part of our responsibility is to help firms decide what their niche should be. Usually the supplier firms have an earlier and better sense of role than the end-product producers.

The third major class of problems must be solved in superconductivity as it must in every other aspect of technology transfer. It is the imperfect knowledge of the federal system and procedures which private firms bring to dealing with national labs.

Most companies tend, in their initial approach, to either of two extremes. One is the expectation that they can walk through the gate, pick up the discovery and walk back out with exclusive rights. The other is the fear that bureaucracy will so bog down the process that no deal is possible. It is the laboratory's job to educate each company, guide it through the process and prevent frustration from sinking the whole enterprise along the way.

The fourth need is for the laboratory to offer a wide diversity of options for transferring the technology. One rigid routine simply will not do the job. There are too many companies of widely varying characteristics, too many markets of widely varying potential, and too many phases of discovery, each of which must have its technology transfer tailored to its character.

Currently we offer about ten forms of cooperation with industry, some of which are employed jointly.

One is collaborative research and development agreements. For example, Argonne and Grumman Space Systems have agreed to a study of surface microstructure and chemistry of high temperature superconductors and their radio frequency properties. This technology transfer relates directly to our SDI program on the neutral particle beam.

The second channel for cooperation is for the corporation to pay Argonne staff to do proprietary work. We are about to sign such an agreement with American Superconductor Corporation of Cambridge, Massachusetts, on sputter-deposited and metal-ceramic bonding of superconductors.

And to show how these techniques can be used in tandem, we are also close to a contract which licenses American Superconductor to use an Argonne patent covering a metal precursor technique.

Our fourth option is work through industrial consortia, a good way for corporations to share the risk and minimize the cost. We plan, when possible, to use the pilot center as a broker in putting together groups of companies with a common interest in some aspect of superconductivity. The work we are negotiating with EPRI falls into the same category.

Another option we have used is combinations of government agencies. For example, the State of Illinois is funding the Illinois Superconductivity Institute which co-sponsored the recent Argonne conference for small businesses and supported the proposal to NSF for an Illinois Science and Technology Center on Superconductivity. A consortium can leverage total government investment to increase research and the ways in which industry can access it.

Industrial residencies and post doctoral appointments also have proven excellent ways to acquaint industry with research underway at the laboratory. We have nine such appointments in superconductivity, including industrial residents from Dow Chemical and Allied-Signal.

One innovation of which we are particularly proud is our Superconductivity Affiliates program. Currently, we have five affiliate members ranging in size from Amex and Amoco to Lake Shore Cryotronics. At lower cost and a lower level of participation, we have associate members like Chevron and BIS Corporation. The advantage of two membership levels is that some corporations are committed and want to work at their niche intensively. Other firms simply want to monitor the field closely so they will know when to step in, or are smaller and have limited funds.

As part of our overall technology transfer effort, we operate a State of Illinois Technology Commercialization Center, which provides a framework to use SBIR's to fund superconductivity projects. Twenty of the 135 SBIR awards recently announced by DOE were in high temperature superconductivity.

Finally, we have a unique option in the Argonne-University of Chicago Development Corporation or ARCH. Patents on Argonne discoveries can be waived by DOE to the University of Chicago and then to ARCH, which serves as an effective negotiator and facilitator to commercialize the discoveries. ARCH also provides other forms of assistance to prospective entrepreneurial collaborators.

One of ARCH's primary advantages is that it can cut down the delays which corporations sometimes face in commercializing a project. ARCH's first license, covering a helium dilution refrigerator developed at the laboratory, was signed within one month after the beginning of negotiations.

As we are structuring our pilot center, it will serve as an outreach organization to make private companies aware of superconductivity advances and the opportunities for collaboration with the national labs. It will be backed by funds to initiate new alliances with industry. It is also industry's communication channel to tell the labs what is needed that is not being offered.

We are recruiting industry executives to serve on the overview committee for the pilot center and will recruit a director with industrial experience either from outside or from inside the laboratory.

Argonne is fortunate in having a university contractor so we were able to set up ARCH and to get fast action on transferring of patents. At the same time, we are a non-weapons laboratory doing very little classified work, so national security concerns have not hampered our tech transfer planning.

Both DOE's Conservation and Renewables program and our local DOE operations office have been very supportive in getting the pilot center launched. All three laboratories are working closely in the development of their pilot centers to assure good inter-lab communications, as little confusion for industry as possible and the sharing of methods.

But as I indicated at the start of my testimony, we still have a full plate of challenges in front of us.

We are solving the question of cooperation with foreign companies pragmatically by making tax and employment benefit within the U.S. the determining factor. We believe the question of exclusivity can be resolved through a two-tiered system where base patents are non-exclusive and "niches" can be licensed exclusively. The laboratories need flexibility to negotiate these deals on intellectual property rights effectively.

We are concerned that few patents may hold up because of intense patenting efforts worldwide. Know-how and data could become increasingly important in commercializing high temperature superconductors. We are working with DOE on the problem of protecting such information and expertise.

Finally, I would like to suggest that the creation of pilot centers and the emphasis on technology transfer in superconductivity is strategically vital to the economy.

Federal funding for basic research and generic applications work has kept us effectively in the scientific forefront. But as the OTA reported this week, private research investment in this country badly lags some of our global competitors, notably Japan. The pilot centers and the superconductivity technology transfer effort generally must play a key role in encouraging more industry participation. We at Argonne and my peers from the other laboratories take this as a very serious responsibility.

Thank you.

HWC:pc
6/21/88

Mrs. LLOYD. There is a fine line, and we do want to work together, and we want to help you. We want to give you the tools so that we can move effectively in technology transfer.

Dr. Hecker.

STATEMENT OF DR. SIEGFRIED S. HECKER, DIRECTOR, LOS ALAMOS NATIONAL LABORATORY, LOS ALAMOS, NM

Dr. HECKER. Thank you, Madam Chairman. It's a pleasure to appear in front of your Subcommittee to share my thoughts about high-temperature superconductivity and about technology transfer.

I do have a detailed statement that I'd like to submit for the record.

Mrs. LLOYD. Without objection.

Dr. HECKER. And I will try to summarize it and focus mostly on the question of technology transfer and try to give you more background about the Superconducting Pilot Centers.

At the hearing on June 10th, a year ago, in front of the Science, Space, and Technology Committee, I made the proposal to have a new initiative for technology transfer from the DOE laboratories to private industry. This initiative involves developing new partnerships or joint ventures with industry. It recognizes the fact that the typical supermarket process of technology transfer just isn't terribly successful.

What I mean by the supermarket process is that all these bright people at the laboratories develop some technology all by themselves, put it up on a shelf, and then basically expect industry to come and get it, and indeed it's from this new initiative that I outlined that we developed the Superconductivity Pilot Center idea.

In this new initiative, the labs do applied research and exploratory technology development with early industry input and guidance in order to make sure that industry provides the market pull for our technology work. The test case that we chose was, indeed, the initiative on high-temperature superconductivity applications. Why choose that initiative?

Our feeling is that because the commercial promise is so enormous, as has clearly been stated already before, the risks are high and the applications are not yet well defined, there's a great amount of R&D that still needs to be done before these materials are going to become useful, and clearly the U.S. is in a tough competition internationally. In my opinion, it's going to take many companies in order for the U.S. to be competitive and not just those few large companies that have made the large-scale R&D investment. It's for all of these reasons that I believe that the National Laboratories need to be involved.

Further, the DOE laboratories also have the proper experience—several decades of superconductivity research and development and also expertise in materials science and technology, which is what it's going to take in order to translate the science into useful products.

Specifically, what I proposed I initially called in the testimony of June 10th exploratory R&D centers at the DOE laboratories. These centers would focus on working with industry on applied research and technology exploratory development—that's what I mean by

exploratory R&D—for high-temperature superconductivity applications to expedite the commercialization of products.

The reason that the labs would focus on exploratory R&D is because I think it's technology development that we do best at the laboratory. It's been the principal assignments in either the weapons or energy-related missions. In the DOE labs, of course, technology development has always been based on a very solid foundation of basic research. Exploratory R&D at the labs will very nicely complement the basic research orientation of universities on one hand and the product orientation of industry on the other hand.

I see the Centers as contributing in any one of three possible modes, and that is, first of all, to conduct R&D on generic enabling technologies that will be important to a whole variety of potential applications. These technologies include areas such as powder synthesis, powder consolidation, processing from the melt, mechanical fabrication, thin-film deposition processes that have been mentioned earlier, and such questions as oxygen stability in these materials. This type of effort will be valuable to all companies, but especially those that can't afford to invest in large-scale R&D.

We view this as driving down the cost of precompetitive R&D, and that's something that the Japanese have shown over the many years that they can do extremely well. Also, I think it's able to make research at universities more useful to industry. In my opinion, this activity should be funded principally by the Government. Of course, in our case that means the Department of Energy. It should receive very strong guidance from the outset from private industry.

The second mode that we can interact is to conduct exploratory R&D jointly funded with industry with applications actually in mind but not necessarily aimed at a specific product. In this case, both industry and the laboratories would contribute people and funding support.

The third mode is to conduct some work directly for industry on a full-cost recovery basis. This could range anywhere from use of the special facilities at the laboratories to some limited product development. This mode, I believe, offers industry the opportunity to test proof of principle concepts before making large investments for development activities.

I should emphasize that the labs must continue to do basic research in the area of high-temperature superconductivity in order to be a valuable resource to industry in exploratory R&D in future years. It is the extremely competitive nature of high-temperature superconductivity on an international scale that demands that the Federal Government take steps beyond simply funding basic research.

Before we submitted the exploratory R&D center proposal to the Department of Energy, we assessed industry interest. We have interacted with over 100 private firms to help us devise an industrial strategy, and let me just briefly summarize the industry comments and their interest.

First of all, I think it is fair to say that there was great interest in working with the laboratories on high-temperature superconductivity exploratory R&D. Second, the industry insists that the DOE and the laboratories clean up the business interface with industry.

What I mean by that, and what they meant, was to expedite and simplify the contracting procedures with the laboratories and to allow industry quicker and easier access to intellectual property rights, and also to be able to help protect proprietary information.

The third aspect of industry input was that the Federal Government must demonstrate a commitment to working with industry through these types of joint ventures. We submitted our proposal for these exploratory R&D centers to DOE in December of 1987. On April 21st of this year, the Department approved the concept in the form of these Pilot Centers that have already been mentioned at Los Alamos, Argonne, and Oak Ridge.

In my opinion, the top management of the Department of Energy has been very supportive of this new initiative with U.S. industry. However, the progress in implementing the initiative, in my opinion, has been agonizingly slow. Just this week, we received some indication of DOE financial support for Fiscal Year 1988 to get the Centers started. We need a commitment for 1989 as soon as possible in order so that we can plan our work with industry. I had previously indicated in my proposal that it would take on the order of $5 million per year per Center for this activity.

In addition to the funding, we must also have expeditious action on the matters of contracting in intellectual property rights. In my opinion, very little progress has been made to date on that matter.

Let me add that the three labs involved in the Pilot Centers have worked together extremely well through the steering committee that has already been mentioned.

Let me assure you, however, that we have not been standing still in the meantime, waiting for the implementation of these Pilot Centers. We have worked diligently with industry. We've already received support from the Public Service Company of New Mexico for high-temperature superconductivity theory, to try to get a better fundamental understanding of high-temperature superconductivity. This is on the order of $570,000 for a two-year effort.

We have several agreements pending with industry, including some of the firms that will be represented later this morning and approximately 20 currently under discussion. We're also looking at working with a number of industrial consortia. I think all the way around with industry there certainly is great interest.

We've also worked closely with the Department of Defense and defense contractors to develop high-temperature superconductivity technology for defense applications. As you heard already this morning, the DOD, in the form of DARPA and SDIO particularly, have moved out very quickly to initiate activities in high-temperature superconducting technologies. We are receiving approximately $3 million of support, most of that from SDIO, some from DARPA, in Fiscal Year 1988 from the Department of Defense.

In addition to exploring the defense applications with this support, there's a natural synergism with the work with industry because much of the generic technology will be applicable to both types of applications even though the applications may be aimed very differently. I think that's one of the benefits of research and development at a place like Los Alamos, and that is that there is multiple pay-off to the Federal investment, multiple in the sense of both for civilian as well as for military applications.

Another common feature to both the DOE- and the DOD-funded work is that we concentrate on trying to do first-rate science, and I think that's particularly important in an area like superconductivity where we have so little fundamental knowledge of what's actually going on.

Because of the press of time this morning, I won't comment extensively on our recent technical progress. I did include a number of specific examples in the written testimony. Let me just suffice it to say that we continue to make steady progress in the area of processing science, areas such as wires, thin films.

Mrs. LLOYD. That's one of the questions I was going to ask you. Why don't you just elaborate right now, and I won't have to ask you the question.

Dr. HECKER. OK. Certainly.

In the area of thin-film technology, for instance, we've been able to process materials by physical vapor deposition into very, very large surface areas, on the area of 100 square millimeters, by a variety of physical vapor deposition processes. We've also used our ion beam materials laboratory to be able to process these films by ion implantation. That holds specific promise in that one is able to make, let's say, layers of superconducting and nonsuperconducting thin films for potential electronic devices by implanting in one case, not implanting on the other, or implanting sufficiently to destroy superconductivity.

We have used some rather novel techniques in melt processing of wire and have actually made 200 feet of the ceramic wire. Unfortunately, to date we have not yet made it superconducting, but we think that will occur, probably in a few weeks' time. But from a processing standpoint, that was quite an accomplishment.

In the area of characterization of materials, we've also made some significant contributions.

So let me just summarize that the high-temperature scientific breakthrough in superconductivity has certainly proved to be as difficult, or maybe more difficult, than everyone predicted a year ago in order to turn it into applications. It makes it even more important, I think, because of that reason, that the U.S. marshal all of its resources, the universities, the industries, as well as the Federal laboratories to expedite the commercialization process. I think the new venture that we have proposed in the Department of Energy has indeed now established the Superconducting Pilot Centers, is a very important step to take the maximum advantage of the DOE laboratories.

Thank you.

[The prepared statement of Dr. Hecker follows:]

U. S. House of Representatives
Committee on Science, Space, and Technology

Hearing On

High-Temperature Superconductivity Technology Transfer

Statement by
Siegfried S. Hecker, Director
Los Alamos National Laboratory
June 23, 1988

I. Introduction

In this statement I will address the current status of high-temperature superconductivity (HTSC) technology transfer, particularly in reference to the involvement of the Los Alamos National Laboratory in the formation of our Superconductivity Pilot Center. The center is being formed as a response to an initiative of Secretary of Energy John Herrington. I will also address recent progress in HTSC research and development and discuss our interactions with private sector companies interested in working with Department of Energy (DOE) laboratories in the HTSC area.

In my testimony before this Committee on June 10, 1987, I stressed that we are in a race to commercialize recent scientific discoveries in high-temperature superconductivity. To compete successfully in this international race, I said that the United States will need to examine and adjust its public policy and industrial strategy. Particularly, I believe that it is imperative that U.S. industry be able to get the greatest benefit from the large federal investment in science and technology, much of it in energy, defense, and space. The DOE national laboratories can play a significant role in research and development to enhance the nation's economic competitiveness. We are now making substantial contributions to both the understanding of and the ability to apply the new ceramic high-temperature superconductors. As I said last June, the time is right to exploit the resource provided by the DOE laboratories and to optimize the benefits to the nation. Finally, I proposed in my testimony last June an initiative to develop an industry/DOE national laboratory partnership by establishing Exploratory R&D Centers at these laboratories.

II. The Herrington Initiative

Subsequent to my testimony, Secretary Herrington asked Los Alamos to "explore private sector interest in the establishment of cooperative research programs to develop enabling technologies for commercial application of superconductivity." Our "effort could lead to a pilot program which if successful will be expanded to other DOE laboratories."

As requested by Secretary Herrington on July 30, 1987, we undertook a study of private sector interest in and models for establishing cooperative industry/DOE laboratory research and development programs for commercial applications of superconductivity. I will summarize here some of the results and conclusions of this study, which we submitted to DOE in December of last year.

A major part of this study involved an intense program to canvass that segment of industry most interested in superconductivity to learn their perceptions and needs. This investigation was an intense short-term activity to gather numerous responses to the

idea of enhanced industrial involvement with DOE laboratories in exploratory R&D on high-temperature superconducting materials. We used a variety of actions and activities to solicit and facilitate input from industry as well as from the other DOE laboratories. We mailed questionnaires to representatives of 98 different companies. In addition, we invited each recipient to participate in one of a series of three workshops hosted by Los Alamos. Those unable to attend one of the workshops received individual invitations to visit Los Alamos at their convenience. Additionally, a representative of Los Alamos visited each of the nine multiprogram DOE laboratories and Ames Laboratory and asked them to provide input regarding activities and levels/sources of funding for high-temperature superconductivity. Several of the DOE laboratories were also represented at at least one of the workshops.

After a delegation from the state of Florida visited Los Alamos, representatives of Florida universities and the state government organized a workshop on high-temperature superconductivity, held in Orlando on December 9, 1987. The workshop was cosponsored by Los Alamos. Representatives of approximately 100 Florida companies attended. Also, the DOE consortium for high-temperature superconducting thin-films R&D -- Lawrence Berkeley Laboratory, Oak Ridge National Laboratory, and Los Alamos -- jointly sponsored a conference on high-temperature superconductivity at Berkeley on December 14-15, 1987.

In all these interactions, we found enthusiastic industry interest in the new superconductors. The companies we spoke with are interested in working with the DOE laboratories and are generally appreciative of the efforts of the DOE and the laboratories to increase the access of the private sector to their R&D capabilities. Some companies are moving rapidly on their own to attempt to develop products using the new superconductors. These companies also recognize the R&D capabilities of the DOE laboratories and are interested in collaborations. Small companies and entrepreneurs look at the DOE laboratories as possible sources of funds, information, personnel, and facilities for the R&D they cannot conduct and/or support themselves. In most cases, companies of all sizes agree that the DOE laboratories should vigorously pursue basic and applied research in high-temperature superconductivity, identify important enabling technologies, provide well-characterized materials to industrial researchers, perform diagnostics for industry, and act as an impartial technical referee where unique measurement and characterization capabilities exist.

Early in our campaign to determine industrial interest, several important facts became clear. First, only one reason exists for industry interest in collaboration with DOE laboratories: assistance in attaining their business objectives. Second, there is a strong recognition that the private sector must move extremely quickly in the area of high-temperature superconductivity to gain a competitive edge. Third, those companies experienced in dealing with DOE laboratories are concerned about the time involved in establishing and gaining approval for specific agreements.

Several companies we interacted with were skeptical of the depth of DOE and laboratory interest in and commitment to technology transfer, largely because they do not see a strong linkage between DOE/laboratory objectives and their own. They feel that the laboratories should not "be a solution looking for a problem, but should respond to industry's ideas and requests without being condescending." They hear the statements we make and want to accept them, but as yet they do not see a substantive commitment of DOE/laboratory resources to

industry collaboration. To quote one company representative, "DOE has to put something at risk to prove their sincerity. We are." It is clear that industry expects any partnership to begin with DOE investment of resources before substantial private funds are forthcoming.

Paramount to any industry/laboratory partnership is the delineation of ownership of information and intellectual property and the protection of proprietary information. These issues came up in the workshops time and time again. Individual companies need time and opportunity to capitalize on the fruits of their investments. The high cost of commercialization by industry (perhaps a factor of 100 over cost of basic research and a factor of 10 over cost of development) underscored their persistent requirement for exclusive patent and data rights. Industry would like to see a simple, clear, and liberal intellectual property policy; speedy resolution of issues of patents, titles, and licenses; an up-front assurance of conditions under which intellectual property rights will be allocated; and assurances that company proprietary information generated in industry/laboratory cooperation will be protected.

III. Los Alamos National Laboratory Experiences with Technology Transfer

Technology transfer in a variety of forms has been occurring at the DOE laboratories almost since their inceptions, but it was not until 1980 that Congress enacted legislation that clearly declared technology transfer from the federal laboratories to be in the national interest. The record of the DOE laboratories in transferring technology to industry certainly includes noteworthy successes. For example, the weapon laboratories -- Los Alamos, Lawrence Livermore National Laboratory (LLNL) and Sandia National Laboratories (SNL) -- have been for decades quite successful in working with, and transferring technology to, industrial contractors within the DOE nuclear weapon community. Los Alamos is now also working on several programs of transferring technology directly to contractors for the Department of Defense (DoD) in the Armor/Anti-Armor program and to contractors with the Ground Test Accelerator for the neutral particle beam program sponsored by the Strategic Defense Initiative Organization (SDIO). In the case of the free-electron laser, another strategic defense research initiative, we are teamed with Boeing Aerospace to develop the radio-frequency free-electron laser concept. These efforts show clear signs of success. Efforts of the weapon laboratories have not been restricted to defense-oriented companies. In the past few years, medical-biological, materials, geotechnical, and instrumentation industries have been particularly active in technology transfer interactions with Los Alamos, and the record shows several successes.

We can identify at least four types of exchanges between the DOE laboratories and industry that have led to successful technological applications: product demand, entrepreneurial spin-offs, contract research, and collaborative research.

The laboratories have had a great impact on certain industries by providing a demand for unique and highly sophisticated technologies, such as supercomputers and high-power lasers. Since World War II, the nuclear weapon laboratories have provided a stable market for innovation with supercomputers and related technologies in the course of fulfilling their nuclear weapon mission. The impact on computer technology and large-scale computational science has been enormous. For more than four decades, while providing a consistent and demanding market for improved products, the laboratories have shared their technologies with industrial firms and have worked with industry to set standards and improve performance.

Employee entrepreneurs who leave the laboratories and start up their own private companies have been another means for transferring innovations to the marketplace. Recent government actions encourage entrepreneurship by federal laboratory employees, and many laboratories actively support such activities. For example, more than 20 company start-ups have emerged from Los Alamos technology spin-offs since 1980.

Contracts, licensing, and institutional collaborations probably provide the most commonly used means for transferring emerging new technologies to the industrial sector. At Los Alamos, contract research activities funded by private firms have averaged several million dollars a year. The DOE laboratories have encouraged research collaborations with universities from the beginning, but it has been only the past several years that they have also received significant interest in collaborations from industry. Institutional collaborations and contracts between the national laboratories and industry have been conducted under six types of arrangements:

(1) The full-cost reimbursable, or "funds-in," arrangement is an agreement in which the sponsor contracts with the laboratory (actually DOE) for a specific research and/or development activity. Under this type of arrangement, the sponsor receives the maximum rights in intellectual property generated (typically assignment of patent rights and unlimited data rights) but must fully reimburse the government for the costs of the effort (e.g., for salaries, overhead, materials). The government, however, retains a royalty-free, nonexclusive license to make use of the technology for its own purposes. Under current policy, all funds-in arrangements must receive prior approval by the DOE.

(2) A jointly funded agreement or joint venture is basically a shared-cost laboratory/industry partnership arrangement in which the sponsor receives no rights to technical data and all such data must be placed in the public domain for all to use unless the data are the subject of a patent application. The sponsor may seek the same patent rights as for the funds-in case, depending upon the relative funding for the project between the government and the sponsor. The DOE must negotiate and approve such agreements.

(3) Industrial collaborations are relationships in which no funds change hands and the industrial partner receives neither data nor patent rights. This arrangement is essentially an exchange of technical information in an area of mutual interest. If this exchange is done under a formal agreement, then DOE must approve that agreement.

(4) User facility relationships are agreements in which the sponsor has access to certain designated user facilities. Such facilities are maintained by the government in part to make available resources that otherwise would have prohibitive costs to users. In a nonproprietary agreement for access to user facilities, the sponsor receives maximum rights to any patentable inventions except for the government-retained nonexclusive license, while technical data resulting from the work are in the public domain. For proprietary agreements, the sponsor fully reimburses DOE for all costs derived from the sponsor's use of the facility. For these agreements, maximum patent rights and unlimited data rights are available.

(5) Personnel affiliates programs are arrangements in which the sponsor's staff joins the staff at the laboratory to engage in on-the-job training or cooperative research, or laboratory staff joins the sponsor's staff at the sponsor's facilities, or there is an

exchange of staff. Costs are usually borne by the party providing the staff (for example, travel expenses, salary) although the recipient may provide some support such as laboratory equipment. Rights in patentable inventions are available depending on the nature of the arrangement and subject to DOE approval. When the sponsor's staff works at the laboratory, no data rights are available.

(6) In a consulting arrangement, laboratory employees are used as consultants to assist in the solution of a sponsor's problem at the sponsor's facility. The employees' salary and travel are paid by the sponsor. There are two general categories of consulting arrangements: the laboratory employee consults on behalf of the laboratory, and the employee consults as a private individual. Consulting arrangements in the latter category are common in most of the DOE laboratories.

Our Laboratory has been aggressive in opening up our research to industry access and in establishing industry/Laboratory agreements. We currently have a total of 30 active agreements in place, mostly of the funds-in type. We have seven designated user facilities and seven industrial staff members at the Laboratory. We are working on 23 pending agreements with industrial companies, the largest of which would provide nearly $9 million to the Laboratory over the next five years.

We and the other DOE laboratories have clearly gained considerable experience in industrial interactions of many forms. There have been noteworthy successes. However, the technology transfer initiatives at the DOE laboratories have been accomplished within the framework of their own missions, be they defense, energy, or research. I believe that the laboratories could do significantly more by becoming more proactive in meeting industry's needs. As noted earlier, industry's expectations are also considerably greater than what has been accomplished to date.

IV. Exploratory Research and Development Centers - A Mechanism for Enhancing HTSC Technology Commercialization

Out of our study for the Herrington initiative and based on our strong belief that laboratories can do more to enhance technology commercialization came a specific proposal to the DOE. This proposal expanded on the initiative I first introduced to this Committee last June. We proposed to the DOE that they make a concerted department-wide effort to take additional advantage of their already substantial investment in superconductivity. We again proposed that DOE establish a network of Exploratory R&D Centers (ERDCs) at its laboratories with the objective of helping U.S. industry develop the enabling technologies necessary for the rapid commercialization of new superconductors.

Private industry has shown great interest in interacting with many of the DOE laboratories. However, industry has also made it clear that the present cumbersome process of contracting with the national laboratories and the generally protective nature of DOE on intellectual property rights make the laboratories questionable partners for most joint ventures. Industry has strongly urged that the DOE revise its policies to encourage and facilitate industry access to the laboratories.

The DOE must expedite and streamline contracting and simplify intellectual property rights procedures. The DOE should develop policy guidelines and then delegate most of the authority for negotiating contracts and intellectual property rights to the laboratory

directors, with final approval authority at the respective DOE operations offices. To initiate these changes quickly, we proposed that such new procedures be tried first on an experimental pilot basis.

We believe that this ERDC initiative will provide the necessary focus and framework for the laboratories' interactions with industry, and with universities when appropriate. The laboratories will enhance the ERDC investment with existing basic research and other applied research funds from government agencies. Five years is an appropriate initial commitment required for the ERDCs.

We envision the DOE initiative to support three levels of activity at the ERDCs:

(1) Conduct research and development on generic enabling technologies that will be important for many potential applications. These applications include areas such as powder synthesis, consolidation, oxygen stability, anisotropy, mechanical fabrication, and thin-film deposition processes. In this activity we expect to interact closely with universities, including formal ties between specific university programs and the ERDCs. Industry will be called upon at the inception to provide guidance and to review laboratory activities.

(2) Conduct exploratory R&D, including jointly funded ventures with industry, to explore technologies with applications in mind. Joint ventures will require industry to support its own activities and the ERDCs to use part of their DOE funds to support efforts by the center staff. The industrial interactions could be with individual firms or with consortia. The host laboratories would offer the maximum possible access to their facilities and expertise consistent with noninterference with the laboratories' principal missions.

(3) Conduct work directly for industry on a full-cost-recovery basis. This work could span the range from exploratory development to some limited product development.

We believe that the need for a network of ERDCs at six or more DOE laboratories is justifiable now. To make a difference to economic competitiveness in superconductor applications, as many ERDCs as possible should be established to work with the multitude of companies interested in superconductor applications. Timing is essential to U.S. international competitiveness. The laboratories and DOE must act as rapidly as possible.

However, we recognize that funds are limited. Also, the changes required in DOE contracting and patent/licensing procedures are sufficiently great that we believe more timely action will be taken if we limit the initial step to an experiment -- setting up a small number of ERDCs quickly.

The pilot program proposed for the ERDCs would greatly streamline the laboratory/industry interface. The laboratories and DOE would jointly develop guidelines for cooperative agreements for laboratory/industry collaborations and partnerships. These guidelines would provide flexible options depending on the needs of the laboratory and industry regarding ownership of intellectual properties, handling of proprietary information from cooperative projects, exclusive licenses, shared funding, etc.

The program should also include a class waiver of patent rights to the laboratories' operating contractors for patents emerging from center activities. Most of the requisite authorities for contracting and patent licensing would be delegated by the DOE to the laboratories' directors with, in some cases, final approval by the DOE operations offices.

This streamlined approval experiment would be run for two years and be limited to the topic of high-temperature superconductor R&D at the ERDCs.

This pilot program would also allow the DOE to assess its concerns about fair access of industry to the laboratories and the potential interference of these industrial initiatives with the primary missions of the laboratories. Industry would be able to evaluate the laboratories' ability to protect proprietary information and the effectiveness of the government's investment in the ERDCs to help industry's international competitiveness. If successful, the pilot program should be extended to a number of other DOE laboratories.

We proposed to the DOE that one of the ERDCs be at Los Alamos. The Los Alamos National Laboratory has a long and distinguished history in superconductivity research. The work at Los Alamos began with the late Dr. Bernd Matthias, who was associated with the Laboratory for over 20 years. The exciting work on heavy-fermion superconductors, largely a result of research at Los Alamos (with many international collaborations), revived international interest in superconductivity when many called the field "mature." From late 1983 to early 1987, Laboratory researchers published over 150 refereed papers on superconductivity. Much of that attention has now been turned to high-temperature superconductors.

Los Alamos has also contributed extensively in superconductor applications. In the late 1970s, Los Alamos, in conjunction with GA Technologies, designed, built, and tested a superconducting magnetic energy storage system for a demonstration of electric power conditioning on the Bonneville power line. Los Alamos also developed and tested a direct-current superconducting power transmission cable in the early 1980s.

Los Alamos has a broad and extensive program in materials science and technology. The Laboratory has one of the most extensive capabilities for materials processing in the United States. The total amount of materials work at Los Alamos is close to $100 million, with $30 million of that total being expended on basic and applied research.

In addition, Los Alamos will be able to complement the DOE and industry-supported efforts at the center with defense-sponsored work on superconductor applications. The defense work at Los Alamos has stimulated an environment appropriate for innovation. We have extensive experience in working with defense industries. We are accustomed to developing technologies with an end product in mind. An ERDC will allow us to establish a working relationship with private sector industries with benefits to both industry and the Laboratory.

V. Implementation of the Los Alamos Superconductivity Pilot Center

On April 21, 1988, DOE Secretary Herrington responded to our ERDC proposal by announcing that three Superconductivity Pilot Centers (SPCs) would be created "to collaborate with industry in advancing high-temperature superconductivity technologies." In addition to Los Alamos National Laboratory, SPCs would be created at Argonne National Laboratory (ANL) and Oak Ridge National Laboratory (ORNL). The announcement said that the pilot centers would be designed "to facilitate collaboration between the laboratories and industry by speeding up the contracting and project approval process and the transfer of patent rights and other intellectual property." Also, the centers would be expected to "enable industry to participate early in the process and to help focus research on the technologies that will be needed to make superconducting products."

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Since that announcement, we have been working with DOE, ANL, and ORNL to develop plans to implement fully the three SPCs. At the same time, we have continued to work with a number of companies in establishing new collaborations in HTSC R&D that will be folded into our SPC as it develops.

At Los Alamos, we have a substantial ongoing HTSC research program funded by a combination of DOE and DoD programs and our institutional supporting research funds. We have made and implemented the decision that all of our HTSC R&D work will be coordinated by a single manager who will head our HTSC Exploratory Research and Development Center, which will encompass our SPC. That person is Dr. Rod Quinn. We are giving Dr. Quinn's activities full support from the Laboratory's management so he can move as fast as possible to establish the SPC as a proactive institution to accelerate the commercialization of our HTSC research and development products.

A key role of our SPC will be to give industry a window into the larger HTSC R&D program at the Laboratory while permitting specific collaborative agreements, some of a proprietary nature, to be implemented in an expeditious manner to meet the needs of industry and to enhance U. S. competitiveness in HTSC development and applications.

The SPC will have the following goals:

(1) enhance U.S. technological competitiveness in the HTSC area,
(2) maintain a strong knowledge base in HTSC science and technology,
(3) advance those unique enabling technologies that represent the greatest potential for commercialization consistent with Los Alamos capabilities, expertise, facilities, and equipment,
(4) develop superior methods of technology commercialization in partnership with industry and academe and experiment with new and novel mechanisms of interaction with industry, and
(5) have industry provide the market pull to guide the development of enabling technologies and incorporate industry expertise in applications, processing, and manufacturing.

The Los Alamos pilot center will have a small cadre of researchers who will provide both a resource for Laboratory/industry partnerships and access to Laboratory capabilities outside the SPC. The scientific staff of the pilot center will have sufficient knowledge and expertise across HTSC science and technology areas to be a resource to industry and to focus Laboratory research in the key areas. The SPC will begin with a focus on three enabling technology themes for potential industry partners:

(1) the development and production of high-current density material/configurations aimed at wires and tapes,
(2) exploratory R&D for dry and solution powder processing, consolidation, and sintering, and
(3) coating development.

Underlying and supporting these themes will be a substantial effort in chemical, physical, and mechanical property measurements.

Our SPC's mission of accelerating the commercialization of high-temperature superconducting materials and processes as an experimental pilot center will be accomplished by

(1) developing innovative partnerships with industry and academe,
(2) performing research and development on key enabling technology within these partnerships, and
(3) working with the DOE to develop streamlined policies for contractual and intellectual property rights, which encourage private sector participation and provide competitive business advantages to the private sector partners.

The technical strategy for the pilot centers is driven by the recognition that the keen international competition that exists in superconductivity will require very rapid commercialization of new scientific advances. The traditional serial approach of innovation (research, development, manufacturing, and marketing) will not suffice. We recognize that the distinction between some of these steps will become smeared. However, we will discuss our approach using these steps to describe our strategy.

The strategy will be to achieve continual input and feedback from downstream stages of the innovation cycle, and particularly manufacturing and marketing, to all earlier stages in the sequence and to tightly couple neighboring stages. For example, materials process R&D will depend heavily on basic research results, and, conversely, materials process R&D and conductor development will help focus research. Also, industrial partners will be brought in as early as possible to provide perspectives on device applications and market and manufacturing considerations.

At this time, device applications and the markets are not well known for commercial applications but are somewhat defined for defense applications. However, we are convinced that both commercial and defense applications will abound if we can solve some of the difficult technical challenges. Initial technical objectives of the pilot center will be oriented largely towards development of configured high-temperature superconducting conductors such as wires, tapes, and thin films. We will set more specific objectives and priorities for the SPC after receiving advice from industry through an External Advisory Board.

Sustaining the HTSC basic research program should be a very high priority for the various federal agencies involved and is essential to provide the base for development of commercializable technologies. Basic research is being pursued vigorously at universities, some industrial laboratories, and government laboratories. These studies are focused on gaining a fundamental understandings of high-temperature superconductivity and at achieving higher-temperature superconductors.

Research activities in our SPC will be directed at understanding the preparation, physical properties, mechanical properties, and stability of high-transition-temperature materials. The main emphasis of these efforts will be tailoring the properties of known materials, while maintaining a smaller effort in the search for new materials.

Technology development will focus on materials processing issues. I have mentioned the main technology targets. Materials processing issues, such as optimizing powder properties, production of thin films by physical vapor deposition (PVD), preparation of thin to thick films from solution routes, and colloidal processing of precursor powders to monolithic forms, will be addressed. The goal is to optimize the electrical and magnetic properties of

these various forms for applications. In addition, specific tasks for applications defined by industry will develop with time, drawing on both the SPC enabling technology efforts and also resources elsewhere in the Laboratory.

VI. Technical Programs and Progress

At Los Alamos, we have a healthy program in HTSC research already under way to provide a strong scientific base from which the SPC can draw. Our total program in FY 88 may total over $7 million in funding, including $2.7 million from our Institutional Supporting Research and Development (ISRD) program, $.3 million from the DOE Office of Conservation and Renewable Energy, $1.2 million from the DOE Office of Energy Research/Basic Energy Sciences, $3 million from the Department of Defense (the bulk of which is from the SDIO), and $.4 million from the private sector.

Our high-temperature superconductivity program consists of three closely coupled elements: basic research, exploratory research and development, and applications development. Our basic research work is funded principally by DOE/BES and internal funds. Exploratory research and development is funded principally by DOE with some funding from DoD. Applications development is funded principally by DoD. Our DoD HTSC programs involve developing both superconducting components for specific DoD systems and also a stronger defense technology base. Many of our SDIO-funded systems, such as the neutral particle beam and the radio-frequency free-electron laser, could be significantly improved by upgrading to high-temperature superconducting radio-frequency accelerators. We are also developing superconductor processing technology for the Defense Advanced Research Projects Agency (DARPA). This work is in collaboration with Monolithic Superconductors, Inc., a small Oregon company. In all DoD programs the Laboratory is teamed with a specific DoD contractor or contractor group. Laboratory/DoD industry teams will continuously support the U.S. manufacturing community in the development of components.

We view basic research as the foundation of our HTSC program. The basic research program is structured to enhance our strengths in two areas: the theory of high-temperature superconductors and the chemistry, materials science and physics of these materials. Basic research directly supports the exploratory research and development activities that are needed to develop the enabling technologies that make new applications possible.

Our exploratory research and development activities are focused on the development of enabling technologies that will result in conductors for generic high-current, high-field applications and in thin films for generic detector, circuit, and device applications. It is in this area of exploratory R&D that the DOE laboratories can help to drive down the precompetitive cost of technology development and give U.S. industry as a whole a competitive edge. Private industry must be involved early to guide such technology development.

Applications are specifically held to a product or system. Our current applications development is focused on magnetic shields, infrared detectors, neutral particle beam radio-frequency cavities, and superconducting motors, principally for defense applications. For commercial applications, private industry must provide the market pull for all applications work.

Our research is producing some solid results; however, our scientists and engineers along with everyone else have found that the transformation of the new high-temperature superconducting materials into prototypical device applications is extremely complex and difficult. Below we summarize some of our recent accomplishments.

(1) Shielding/Trapping Asymmetry in Sintered Powders and the Modeling of Flux Lattice Shear Strength

An unusual effect has been seen in measurements that compare the magnetic shielding and magnetic trapping properties of superconducting cylinders made from sintered powders of the standard 1-2-3 (Y-Ba-Cu-O) ceramic superconducting compounds. These cylinders are found to trap almost twice as high a field in their interior as they are able to shield against. For conventional superconductors the value of these two fields, shielded and trapped, would be equal because the superconducting properties depend only on properties of the sample that are equal for the two cases.

One explanation of this new shielding/trapping asymmetry is based on the extreme material heterogeneity of the sintered powder samples. Each grain or crystallite of the sample is an excellent superconductor that can strongly pin magnetic flux lines. However, these grains are surrounded by "weak link" material, which constitutes the continuous phase and is a region of relatively poor superconductivity and intrinsically low critical current (weak pinning of flux lines). The combination of strong and weak pinning regions causes the overall motion of flux lines in the weak links to be inhibited by the presence of those flux lines that also pass through, and are thereby strongly pinned, by the grains.

The result is a new dependence of the effective critical current in sintered powders on the magnetic history of the sample: if the grains contain pinned flux lines as a result of previous magnetizations, then the critical current of the bulk sample can be larger than if the grains contain no flux lines. These results suggest the possibility of tailoring the critical current of multigranular HTSC materials by controlling their magnetic history and of enhancing the coupling between the strongly and weakly pinned flux lines, thereby increasing the critical current by controlling the size and shape of the weak link channels, as in melt-textured growth.

(2) Radiation Damage Studies of the 1-2-3 High-Temperature Superconducting Compounds

A detailed study of the sensitivity of the 1-2-3 compounds have shown they have good structural stability under high doses of ionizing and electron irradiation. The damage associated with the rare-earth component (such as gadolinium or yttrium) is a key process in destroying superconductivity. Further, it was found that the amount of damage produced by a given amount of radiation depended on the specific rare-earth element present. For example, the gadolinium-123 compound is less sensitive to damage than the yttrium-123 compound by a factor of 3 to 4. Resistance of these new high-temperature superconductors to radiation damage (gamma rays, energetic ions, neutrons, etc.) is of concern for applications such as fusion reactor magnets and SDI components because the damage can significantly affect performance.

(3) Ion Beam Processing of Superconducting Thin films

Los Alamos was the first laboratory to report successful formation of $YBa_2Cu_3O_7$ by implanting Y into a base material of BaF_2 and Cu. Subsequent annealing in O_2 resulted in forming a thin film of the superconductor in the implanted region. As noted above, ion implantation can also destroy superconductivity at moderate irradiation doses. This fact allows, with the use of masking techniques, the ability to form printed circuit patterns of superconductors. An alternative process is to start with a nonsuperconducting base material and use ion implantation to form the superconducting phase only in the implanted region. These two approaches demonstrate that a wide variety of superconducting thin-film architectures could be developed by ion implantation.

(4) Low-Resistance Electric Contacts

Achieving a low-resistance electrical contact with a high-temperature superconductor is extremely important both in actual application and in the measurement of current carrying capability. In actual use, the heat generated at a contact at best increases the load on the cooling system and at worst risks driving the superconductor normal. Similarly, heating at contacts while attempting to measure the current carrying capacity of the superconductor may lead to a serious underestimate. Los Alamos has achieved excellent results in developing contact procedures for both bulk samples and thin films. A very effective and economic plasma spraying process has been developed to deposit a layer of silver on bulk superconductors. Contact leads are then easily soldered to the silver resulting in a contact resistance significantly better than any other method reported in the literature.

We have also developed a somewhat more resistive but very effective contact procedure for transferring electric current into thin films using platinum, gold, or silver. This process uses procedures similar to preparing an electronic printed circuit. Combining the printed circuit technology to produce a metal pattern with the use of an oxygen sputter-etching technique to clean the surface of the superconductor produces excellent adhesion of any of the three metals.

(5) Thin-Film Superconductors

The development of reproducible, high-quality thin films is essential to realizing some of the most exciting applications of high-temperature superconductors in electronic devices. Los Alamos has focused an effort in this area with significant contributions in several areas. We can now routinely prepare high-quality films (transition temperature greater than 85K) of $YBa_2Cu_3O_7$ using two different physical vapor deposition techniques, and the deposition technology has been scaled to allow uniform deposition over large areas exceeding 100 cm^2. Using this capability we have also learned that high-quality thin films can be stable in air for several months with little degradation. The characterization of thin films (composition and the presence of nonsuperconducting material) is important in fabricating reproducible films and in understanding their properties. We have developed a unique compositional characterization capability for thin films using high-energy backscattering techniques including but not limited to Rutherford backscattering. We are also studying a promising correlation between transition temperature and information on composition obtained from Raman spectroscopy.

(6) Fabrication of Superconducting Wire from the Melt

Fabrication of low-temperature metallic superconductors from molten ingots was never commercially pursued, in part because of their high melting points. In contrast, the $YBa_2Cu_3O_7$ material melts at a relatively modest temperature, and the new thallium-based compounds have a still lower melting point. Thus, melt processing is a promising category of approaches that may provide relief from some of the problems plaguing powder consolidation, such as poor intergranular contact (the weak-link problem). Los Alamos, in close collaboration with the University of Missouri-Rolla, is aggressively pursuing an approach developed by the British for producing metal microwire called the "Taylor wire technique." In this approach, a glass tube with a neck at one end is filled with the superconducting material and heated in a precise manner in the neck region. When the superconductor is molten and the glass softened, the composite is drawn into a wire. This process produces a fine continuous wire rapidly cooled from the melt and is expected to introduce texturing or

orientation of the individual crystal grains important in achieving large current carrying capacity. We have demonstrated production of 200 ft. of nonsuperconducting composite wire from YBa2Cu3O7 and are currently developing barriers to prevent the reaction between the glass and the YBa2Cu3O7 which is degrading the superconducting properties.

VII. Recent HTSC Interactions with Industry

While working with DOE to establish our SPC, we continued interactions aimed at developing new partnerships in HTSC R&D. One successful interaction began while we were working on our study for DOE last fall. The Public Service Company of New Mexico (PNM), along with US West, began a significant private initiative to develop a clear businesslike approach to partnerships between industry and national laboratories. PNM and US WEST proposed a Work for Industry Program (WIP) to improve the opportunities for U.S. companies to contract directly with DOE laboratories for specific technology development projects. A comprehensive plan was developed for establishing new rules for expediting direct negotiations and contracting between DOE laboratories and companies. The commitment of time and effort to this private initiative is indicative of strong industry interest in cooperative R&D with DOE laboratories. As a further indication of its interest, PNM worked with DOE and Los Alamos to fund a PNM Fellowship that has brought Nobel Laureate J. Robert Schrieffer to Los Alamos part-time to work with scientists on HTSC theory.

One of the more likely areas for SPC support of small entrepreneurial companies is in material characterization using the unique facilities at Los Alamos. We have now signed an agreement with Superconducting Technologies Inc., of Santa Barbara, California, to conduct collaborative research using the Los Alamos Ion Beam Materials Laboratory. The DARPA Superconducting Materials Program provided the stimulus for initial discussions leading to this agreement.

Serious negotiations are under way with Rockwell International to conduct collaborative research focused on the fabrication development of high-temperature superconducting Tl-Ca-Ba-Cu-O, Bi-Ca-Ba-Cu-O, and Re-Ba-Cu-O powders for utilities applications. The collaboration resulted from the new research program of the DOE Office of Energy Storage and Distribution in the Office of Conservation and Renewable Energy. The program is focused initially on moving HTSC from the laboratory to commercial products including superconducting wire, thin- and thick-film conductors, and special devices for power systems. It is anticipated that Bechtel, Inc. will also collaborate with Los Alamos on this project.

Our collaboration with Monolithic Superconductors, Inc., (MSI) was mentioned above. We submitted a joint proposal with MSI to DARPA to investigate shock consolidation and extrusion of HTSC powder materials using explosive charges. This effort leverages off many years of DOE- and DoD-funded explosives work at Los Alamos. We have now determined the operating regimes that result in consolidated material that is fully dense and free of microcracks.

We have ongoing discussions with several other companies about establishing collaborative R&D agreements of various kinds. Over 20 companies have expressed interest in entering into collaborative R&D efforts with us, and we are actively pursuing these possibilities. We are currently working with two companies to establish proprietary research contracts wherein Los Alamos would perform research in areas of specific interest to the companies. In one of these we are negotiating with the research arm of a major manufacturer to begin a collaborative project to characterize the radio-frequency performance of high-temperature

superconductors and pursue basic research into new superconductors for even higher temperatures. Finally, we have recently submitted our first HTSC patent application. Through a competitive process, we have selected a licensee for this patent and are negotiating a patent agreement. We trust this accomplishment presages many future such agreements through our SPC.

VIII. Where Do We Go From Here?

It is more than one year since I first proposed to this committee the establishment of HTSC Exploratory R&D Centers at the DOE laboratories. The DOE laboratories have been moving forward in HTSC research and also in developing new interactions with industry in this rapidly evolving area. Under the guidance of DOE, we are now working with our sister laboratories at Argonne and Oak Ridge to establish Superconductivity Pilot Centers.

The progress is promising, but agonizingly slow. Our Japanese colleagues have not hesitated in pulling their university, laboratory, and industry resources into integrated teams to push HTSC technologies rapidly towards commercialization. In the United States we continue to make excellent progress in research. But we must develop new attitudes and new modes of interaction among our universities, laboratories, and industry to compete in the race to commercialization. I believe that the DOE Superconductivity Pilot Centers are an important experiment. They will help to develop the new partnerships between government and industry and make the United States more competitive.

Mrs. LLOYD. Thank you very much. All three of you provided excellent testimony, and I hope those in the audience—of course, all of our testimony is very fine, but Dr. Zucker attached an article that appeared in *Science* on the struggle to promote spinoffs. I think it really points up just where we are, that we're spinning back $20 billion a year, the Federal Government, in R&D.

Most of our R&D experts agree that little laboratory technology has found its way to the marketplace and that one of the obstacles is a reluctance to sign contracts, where the Government is reluctant to allow private industry to sign contracts giving them exclusive rights, and therefore they were losing the marketplace advantage, and one of the reasons we are here today is to see what we can do better to overcome these impediments. This is a serious problem. We're wasting R&D dollars, valuable talent, and we simply cannot continue.

What are the major difficulties, as exemplified in this program specifically, to generate agreements between companies, and what are our solutions?

Alex?

Dr. ZUCKER. Well, let me start by saying that the Government has done a great deal to facilitate these connections. The passage of various acts, legislation, for the past five to ten years in the areas of antitrust, in the areas of access to laboratories, and broadening the ability for the laboratories to work with industry. I think Government has done a great deal.

Industry is really not aware of all the things that have happened, and for reasons that are just not terribly clear to me there's no stampede by industry for all these good things.

Mrs. LLOYD. Is this, too, the supermarket?

Dr. ZUCKER. Well, it isn't the supermarket, really. We and Los Alamos and Argonne, too, market specific things which we know industry wants. We spend a great deal of effort, and we have, in the final analysis, a great deal of difficulty doing that. I'm sure my colleagues as well as I, we ask ourselves the question, you know, "Why, when we open the door, is nobody there"?

One problem is speed. As was indicated by the last set of speakers, a year in a highly-competitive industry in development, technical development, is a long time. If it's going to take a year to negotiate a contract, industry is just not interested, and I must say that several months, four to six months, is not uncommon. So we, the Department of Energy, the Government—everybody—needs to realize that things should not take months; they should take days, and that's not impossible because the track has been laid; we know what we want to do. The problem is solvable, and I hope that these Pilot Centers will really develop these connections to the extent that we can sign contracts in a matter of days or, at most, weeks. If we can't, we have real problems.

But we also have a deep cultural change that we have to develop. It cannot happen overnight. Industry and Government have been at opposite ends in this whole business for the last 80 years, and a recognition by industry that the Government is here to help them,

that's generally greeted by laughter, and it has to be taken seriously. It's not looked upon like that, say, in Japan.

Finally, I'd like to say something that struck me as being a real problem on the part of industry. In this country, an assignment of an industrial engineer or manager to a National Laboratory is tantamount to being sent to Siberia. Nobody wants to go; that's not the way to promotion; that's the way out. In Japan, an assignment to a Government, an MITI laboratory is a sign that the light is shining on this particular person, that his or her path to the future is made.

So there are a lot of these cultural things that we are dealing with that have to be changed. We're not going to change it with one piece of legislation, we're not going to change it with one hearing, we have to change it by continual insistence that there are things to be gained this way in every possible way. You have to say that, we have to say that, the media have to say that, and I hope that in a few years it will happen. We have to work very hard to make it happen.

Mrs. LLOYD. Well, the work that you are doing is a source of national pride and a source of pride to me, to all the Members of this Committee, and we want to do what we can to help you. That's the goal of this Committee. It's one of our major goals as we exist not only as individual Members but as a body.

Dr. ZUCKER. Well, speed; I think at this point it's a matter of speed.

Mrs. LLOYD. Professor Schriesheim, do you have any comments you'd like to make in this area?

Dr. SCHRIESHEIM. Following up on, or maybe emphasizing or reemphasizing one or two points that Alex made, it's certainly within the current system to rapidly conclude agreements with industry. Our experience has been that in some cases it's more a people-related issue than it is a system-related issue; that is, people in the chain need to understand that the current climate, this globalization of innovation—we talk about globalization of financial markets; of course, it's a globalization of technological innovation with other countries having the capability that we now have to move very rapidly, and it's the understanding on the part of people within the system that a rapid completion, a simplified rapid completion, of these contractual relationships is desirable.

In terms of systematics, I think I might go back to something I said during my testimony. We really should take a look at the Freedom of Information Act and how that impacts on our ability within the laboratories to transfer know-how, not so much an actual patent, of course, because once you have a patent that's protected, but it's the other kinds of intellectual property.

The difficulty—let me phrase it differently. The drive for quarterly profits, discounted cash flow, the fact that so many industrial decision-makers look over their shoulders at who's coming after them, provides a certain climate that makes it more difficult for the research people to couple into what is essentially a longer term operation, which is what we represent in the Federal laboratories.

So digging deeper into the system certainly requires, I believe, digging into this whole issue of the corporate tax treatment of this

wave of restructuring and takeovers, which impacts, clearly impacts, on this Nation's R&D capability.

Now I must say I have found more willingness on the part of corporations to leverage their resources with the National Laboratories, understanding that we do represent something which they really can't buy because they don't often have the decision-makers who are willing to allocate long-term funding. Now that, I think, is a real challenge.

Thank you, Madam Chairman.

Mrs. LLOYD. Dr. Hecker.

Dr. HECKER. I would like to also add to those comments and say that it will take a cultural change, a cultural change in all the parties involved, at our laboratories themselves. I think we're in the process of making that cultural change, and that is that we would work not only for the Federal Government as a customer but also for private industry and that we need to let go of the ideas earlier than we're probably used to doing it now.

We need a change in industry, as Dr. Zucker has already mentioned, although I think industry stands to be convinced that the Government can be a reliable business partner. And we need a change within the Government, within our Federal agencies, to worry not so much about letting some particular contract get away and worry about the risks that are associated with that, but more to try to expedite, and I think Dr. Zucker said it exactly right: we need to expedite the contracting and the intellectual property rights so that we can be a reliable partner with industry, especially in areas like superconductivity where it's going to be important to react quickly. The Government and its laboratories will have to be able to do that before we're accepted by industry.

Mrs. LLOYD. Mr. Morrison.

Mr. MORRISON. Thank you.

I find this really rather interesting, because one of the struggles this Committee goes through—and you gentlemen have helped us in it when you wear some of your other hats—is where we draw the line between funding of technologies that are ready to be moved into the marketplace. In essence, what you're saying about superconductivity is that we're all wrestling with where we draw the line and what sort of mechanism you provide through our National Laboratories to get customers through the door. I heard the term "supermarket" mentioned. I think we're probably more like a wholesale warehouse at the moment, and people are afraid to come down the alley and even find you.

Along those lines, Dr. Schriesheim, I'm very interested in your hotline concept. Could you tell us a little more how that works, and these 1,500 calls you've gotten, are people using this to break through the barriers, if you will?

Dr. SCHRIESHEIM. Yes. The hotline is operated by our technology transfer center. The three labs that you see here all in different ways have a technology transfer center that is structured according to their own operation. We have a separate technology transfer center with a separate group that is in charge of that.

The divisions that are involved in superconductivity within the laboratory all have a representative who is the main contact point between the divisions and the technology transfer center. So the

person who is actually responsible for answering these telephone calls has his or her contact within each one of the operating divisions, so they know what goes on in technical detail within each one of these operating divisions.

We announced this hotline in the trade journals, in the press, in speeches; we announced the hotline in superconductivity conferences that we gave; and I, frankly, was surprised at the number of calls that came in to—through the hotline to the technology transfer center. In many cases, the individual manning the telephone, if you will, could answer the questions. In any number of cases, what this individual served was as a transfer point to orient or direct the caller to the actual division doing the work.

So we have gotten calls from—that, on one hand, range from venture capitalists who want to know whether they should advise their clients to buy yttrium and barium oxide to small manufacturing companies who want to get some kind of an insight into what the latest technology is to make a coil, or Dr. Hecker pointed out what goes on on surfaces, what is the latest technology that goes on on surfaces, on up to utilities who are interested in where we stand on superconducting magnetic energy storage, and some of these contacts then have led to companies actually coming into the laboratories.

So when we talk about technology transfer, I view that as a very real success story in the National Laboratories' dissemination of this kind of information out to American industry. It's almost impossible to get the kind of information that our technical people have in concentrated form without having some kind of a lead into the laboratories such as that.

Mr. MORRISON. I find that very interesting, and I admire your innovation, in fact in all of the laboratories, even in those not represented. I'm aware of this effort.

Madam Chairman, I wish the world knew a little more of the efforts that are being made here in technology transfer, and I think superconductivity just happens to be the topic of the day. It's perhaps symbolic of a lot of other technologies. I'd love to see us establish the mechanism. I think we've gone a long ways toward it.

I wonder what we could do on the other side of the equation, and that is on the private enterprise side, on getting them to come a little closer to understand, accept, work with the institutional changes we've already made. Maybe a letter to the Ways and Means Committee encouraging a capital gains tax or some other things are items that I hear about.

But thank you. You certainly have made us think, and I think we're very proud of the progress you've helped us make.

Mrs. LLOYD. We're inspired by the progress you've made, I might add.

Mr. Fawell.

Mr. FAWELL. Yes. Thank you.

I would certainly join in the comments that have been uttered already in regard to the coordination and the progress that has been made here, and yet, Dr. Zucker, you lamented quite correctly, I guess, you opened the door but there's not that crowd out there that you'd like to see, and I'm sure there are other ways perhaps in which to lure those who ought to be interested to take advantage.

I wonder if in any of the three labs involved—and I'm not aware of this, as to whether it is so at Argonne or not, though it is located in the center spot of the universe in my district—whether you followed this, but there is indication, I think, from all three of you that the negotiating process being so long and slow perhaps turns industry off.

Have you thought of, or do you have on staff, experts, attorneys, for instance, who are knowledgeable in the patent process and the licensing aspects, who could be ready, willing, and able to help in the negotiating process? Is that something that is being done or worthwhile to think about?

Dr. ZUCKER. Mr. Fawell, they are part of the problem, and there are three sets of attorneys that we deal with: our own attorneys, Department of Energy attorneys, and industrial attorneys. We've got three sets of attorneys together, and time flies.

I'd like to just put that time issue again in context. The time between the discovery and commercialization of a product used to be 15 years, 30 years ago. It's now, in many cases, down to three years, and in high-technology areas, which is what we're talking about, the time really is about three years. So the loss of a year, that's a third of the whole process. You can't afford to spend a year negotiating or half a year. I think that's part of the problem.

I'm assured that things can be speeded up to the point where it will take weeks, but I was amazed at your one month number. I thought that was some kind of a record. You must have greased the skids for that one.

Dr. SCHRIESHEIM. Well, I assure you it's factually correct.

Dr. ZUCKER. I believe it.

Mr. FAWELL. One of the areas that hasn't been discussed is looking at it from the corporation viewpoint. They have also protection of proprietary interests of perhaps unlicensed, or perhaps licensed, areas, and I know of several instances where they're concerned about their secrets being let out to the laboratory staff and then they lose control, and so they seek protective contracts in that regard.

As an attorney, I know that that can be worked out, and it does seem to me that if you had somebody in the local labs who really practically understood this and did have communications worked out with the DOE, for instance, so they were comfortable in working with him, the average attorney representing the corporation really doesn't know much about licensure law, patents, or things of that sort, so you've got the problems of the patent as viewed from the National Lab and protections which obviously are necessary. But it works the other way, too.

So you've got two conflicts here, both of which have to be thought about and protected, and I know of several instances where people just didn't want to even go near public entities because they had too many secrets of their own. They thought it would be blabbed out and they'd lose it, so you've got that to worry about.

Dr. SCHRIESHEIM. The point that you make, of course, is an excellent one, and we face that. My two other laboratory directors sitting here with me have lots of experience as well as I on that particular issue, and that is the issue of attempting to cut a deal, if

you will, with a corporation that has a large legal staff who are charged with the responsibility of protecting the corporation.

It's been my experience, been our experience, that if the decision-maker at the corporation wants to have a relationship with the laboratory, then the legal staff will spin out the concerns, then in all cases a deal will be cut.

So it's more a matter, I believe—again, as I said earlier, it's really a people-related issue. It's the belief on the part of people that this relationship will actually be profitable for the corporation and, of course, for the laboratory, and that has all these other implications, the tax implications and all those other implications: How best can a corporation assimilate the technology and actually make a buck on it, so to speak?

It's certainly easy for either the lab or corporation to hide behind the legal staff. That's so easy to do. What can we do to help in that? Certainly I think what the three of us are talking about today goes in that direction. We all have people in the lab from corporations. We've certainly made deals, as I mentioned, with Dow and Allied-Signal and Borg-Warner before it was bought up and took care of the legal implications.

Mr. FAWELL. Just to conclude my thoughts, it is definitely a two-way street of corporations understanding Government, which they don't; they're profit motivated; Government is not profit motivated; and so it is a two-way street.

I can think of one instance where an entity did want to go to a particular lab. It was a burning desire. But I could not get through to them to comprehend that they wouldn't be robbed of all their secrets, and they just plain walked away from it. Maybe it couldn't have been done, but I just stress the fact that someone on staff who can put the other attorneys at ease and also can cut through a lot of the legalese that rose up just as fast as can be so that communications with DOE or whatever governmental entity would be helpful in trying to work out that negotiating process. As an attorney, Dr. Zucker, I would agree with you that we get three attorneys together and you can have an awful lot of problems unless somebody has gone through this a lot as an attorney and can sit down with the other attorneys and say, "Look, Joe, I can put you at rest. Here's how it's done," and so forth, and educate him as a practical matter.

Thank you, Madam Chairman.

Mrs. LLOYD. Thank you very much.

Mr. Kanjorski.

Mr. KANJORSKI. Yes, thank you, Madam Chairman.

Dr. Zucker, and the others, if I may, is this completed technology you're talking about, or is this something that's an additive to the process that is going on in the company? In other words, are you trying to market something that is completed as a commercial unit and you're finding it difficult doing that?

Dr. ZUCKER. Perhaps the best thing is if I were to illustrate it. We've been quite successful in marketing new materials, and usually the material will be complete in the sense that we have developed a new composite, say, and we know its uses and even have data for that material, and that is difficult to market—well, that's not so difficult to market. In some cases, we have things where we

have developed a material but not really done all the processing that a commercial operation needs, and then we rely on the industrial partner to do that. That makes it more complicated.

To complete a technology development, the cost goes up very quickly. It's relatively cheap to develop a prototype, but once you go into the development stage to the point where you can now manufacture the stuff, that cost is very high. The laboratories don't have that kind of money, and the industry is reluctant then to invest in this high-cost end to develop the article or whatever it is you want to do to be marketable. That takes a lot of convincing and a lot of salesmanship.

Mr. KANJORSKI. Let me ask something. Is the difficulty, though, of the contractual arrangement as to what the Government or the laboratory gets paid back in the participation of this technology? In other words, if we established a new free zone enterprise where the Government participated as an equity owner for the benefit of, say, all the citizens, and we're able to go in and say to any company that wanted your technology, "Sign this simple agreement. You take it. We'll participate in the profits," a third of the profits, or share some of the costs perhaps if there's a failure. Would that expedite something?

Dr. ZUCKER. We require no participation in the profits at all. Industry gets all the profits.

Mr. KANJORSKI. You're just trying to get the technology out?

Dr. ZUCKER. No. We're doing two things. We're trying to get the technology out, and we do keep patent rights. We don't give those away because, in my opinion, if you give them away you have no march-in rights; a company will just take the patents, sit on them, and nothing will happen. So we require certain progress in the exploitation of a patent, or we take it back.

Mr. KANJORSKI. I'm trying to envision something we're working on another Committee I'm on. If we were to create a new type of corporation, a decontrolled corporation, in which the people participated in the equity ownership and it was sold out in discounts and excess work in companies, accumulated in one public corporation, could we free up an entity that we could create a facilitator that would take your technology to a known needer of it in the industrial complex and say, "Look, if you will put this in a separate superfree corporation where the Government corporation is a participant, we could do this in a matter of two weeks"?

Dr. ZUCKER. I think Dr. Schriesheim has an operation somewhat like that, and I think I'd ask him to do that.

Dr. SCHRIESHEIM. We have established a corporation separate. Our contractor is a not-for-profit contractor, the University of Chicago. We—that is, Argonne National Lab—and the University of Chicago have set up a separate, wholly University of Chicago-owned subsidiary, if you will, called ARCH, for Argonne and Chicago—ARCH Venture Corporation.

The concept is essentially really simple and simple to articulate also to industry, although there are in working things out, obviously, some difficulties. Let me articulate it. Intellectual property, as evidenced by patents, can be waived by the Department of Energy to the University of Chicago as the contractor. The University of Chicago can then place those patents, if you will, into this now sep-

arate corporation. The separate corporation can do all the kind of deals that you mentioned that any corporation could do: joint venture, limited partnership, license, set up companies and take equity participation, get funding from venture capitalists and put that money into the operation.

The refrigerator, helium dilution refrigerator, that I mentioned earlier that we got out within a month was essentially a patent that was picked up by the University of Chicago, deposited in this separate corporation, and the corporation then did the deal, so that it was licensed.

Now licensing income, for example, then flows back through ARCH to Argonne National Laboratory and to the inventor, and a piece sticks with ARCH to run ARCH, and a very small piece goes to the University of Chicago.

Technology from the University of Chicago has exactly the same flow path, so some small part of that then would go to Argonne National Laboratory, for example. So this then is a mechanism, a device. Now it's not the sole device. It obviously is not the only way that Argonne National Laboratory interfaces with industry, because there are a whole series of what is known as "work for others" type of arrangements where we work with industry directly. So there are lots and lots of relationships.

But this certainly so far—and it's only been in existence less than two years—seems to be at least an experiment that appears to be worthwhile. We'll have to look at it at the end of five years and say, "Well, has it returned more than it's cost to date?" and I might point out that the funding of ARCH comes about because the university took $5 million from its endowment and put that to work in bonds, and then the cash flow from the bonds goes to fund this operation. So it's a very real risk money, if you will, on the part of the University of Chicago.

Mr. KANJORSKI. Are your people readily available to talk to us in regard to give us the experiences they've had and suggestions?

Dr. SCHRIESHEIM. I'll certainly make them available to you.

Mr. KANJORSKI. If I may ask the other two directors, do you have other similar ongoing experimental programs that would be worthwhile to talk to?

Dr. HECKER. We don't have the program of the nature that Al Schriesheim referred to, but we've certainly given a lot of thought as to how to try to get the technology out. I'm not sure that that's our biggest problem. I think if we could clean up the business interface to work quickly with industry, the main effort is exactly as Alex Zucker had mentioned, is that you want to get the licensing right to industry to have them develop the technology.

Mr. KANJORSKI. Do you have someone in particular at the lab that's working on that——

Dr. HECKER. That's correct.

Mr. KANJORSKI [continuing]. That if we take some of our vacation time and come up and talk to them——

Dr. HECKER. We'd be happy to work with you, yes.

Mr. KANJORSKI. Okay. Thank you.

Mrs. LLOYD. Thank you very much, Mr. Kanjorski.

One final question, Alex. You mentioned HFIR in your testimony. Do you think August, 1988, is a realistic starting date?

Dr. ZUCKER. I certainly hope so. We're now in the thirteenth week of our restart plan, and in the last 13 weeks we have not slipped a day.

Mrs. LLOYD. Do you see any unwarranted bureaucratic impediments?

Dr. ZUCKER. Yes, I see them.

Mrs. LLOYD. That you want to talk about.

Dr. ZUCKER. All the time, very clear. The ones I see I think I can handle. It's the ones that spring out of the bushes that I'm thinking about, and we are doing everything we can. The Department and the Oak Ridge Operations Office are, of course, eager to get the reactor started, and I certainly hope that it will start, and I would like to enlist your help to make sure that——

Mrs. LLOYD. We'll certainly do what we can, and, again, thank you, gentlemen, for being here. We appreciate what you're doing at our National Laboratories.

PANEL 3: INDUSTRY

Our final panel consists of the group which we hope will be made competitive by the agency and departmental activities about which we just heard, the industrial sector. It seems to me that you're where the action is.

It is nice to see you today. You know the negative cliche: "We're the Government; we're here to help you." But I think you've heard that our groups are trying to do just exactly that in superconductivity, and we want to know from you just how well these programs are working.

We have Dr. Bill Black from Biomagnetic Technologies; Dr. Nick Eror from Monolithic Superconductor; Mr. Jerry Lloyd, Emerson Electric; and David Conrad from Allied Signal.

Dr. Black, you please go first, and, gentlemen, your entire statements will be made a part of the record. You may summarize if you wish, and all of your statements will be made a part of the record.

Dr. Black.

STATEMENT OF DR. WILLIAM C. BLACK, JR., SENIOR VICE PRESIDENT, BIOMAGNETICS TECHNOLOGIES, INC., SAN DIEGO, CA

Dr. BLACK. Thank you for the invitation to testify today.

My perspective on commercializing high-temperature superconductivity is based on an experience with a small company that has been manufacturing instruments with superconductor technologies since 1970. Biomagnetic Technologies, Incorporated, or BTI, employs abut 95 people. We anticipate product sales of $6.5 million for our Fiscal Year ending this September.

Until about four years ago, we built specialized equipment sold mainly to low-temperature physics laboratories. In 1984, we decided to reorient our business into an entirely new area with much greater growth potential. Using the superconductor technology we had perfected over the past decade, we had developed an instrument with the ability to examine disorders of brain function in an entirely new way—common disorders such as stroke, epilepsy, dyslexia, schizophrenia, and Alzheimer's disease. This new technique

involves measuring the weak magnetic fields produced by brain electrical activity. It is known as magnetoencephalography, or MEG. MEG provides a sensitive, noninvasive means to track which parts of the brain are working at any given instant of time. This would be impossible without using extremely sensitive superconducting magnetic sensors.

Our present products are based on conventional superconductors refrigerated by liquid helium. For research groups exploring the frontiers of how the brain works, the extraordinary new window on brain function provided by our instrument justifies raising funds to pay the $1 million price tag. Our goal over the next few years is to develop a cost-effective system for routine clinical use.

While we believe we can do it with conventional superconductors, the requirements of liquid-helium refrigeration present an engineering challenge that would be enormously simpler if we were able to operate the sensors even at liquid-nitrogen temperature.

With the right superconductor materials, a lightweight helmet-like device could replace the current dual sensor units which weigh 100 pounds apiece and require elaborate, expensive gantries to position them around the head. We believe high-temperature superconductors could have a tremendous impact on the size of our market by reducing the cost of the equipment and making it very much easier to use.

BTI has received $1.8 million from the Small Business Innovation Research, or SBIR, program. All of this support has been for projects directly related to our product development, and essentially all of it has come from the National Institutes of Health.

Although the Government has supported only a fraction of our total R&D expenditures over the past few years, it has had a disproportionately favorable impact. First, it enabled us to tackle some projects that we could not otherwise have done, and fortunately they were very successful. Second, NIH support for our product ideas was a significant factor in raising two rounds of venture investment capital totaling over $10 million.

It is too early to tell whether or when high-temperature superconductivity will be useful for our products. Therefore, we cannot put it in series with our product development plans over the next three to five years. On the other hand, high-temperature superconductivity is potentially too valuable to be ignored, and we must be prepared to adapt it when it is possible to do so.

But even though the potential benefits to our business may be clear, the cost and time to develop them are not, and since those key risk evaluation factors are not yet quantifiable, we could not afford to undertake meaningful R&D effort in high-temperature superconductivity without incremental funding from the outside specifically for this purpose.

None of our previous Government support has involved high-temperature superconductivity research, but we have been notified of two awards in this area. Unfortunately, both of them are held up by a spending freeze at the Department of Defense resulting from a directive issued last month by Deputy Secretary of Defense William Taft.

The goal of technology transfer should be technology commercialization. Commercialization is where our society stands to realize

the benefits of this or any new technology. Why does the U.S. seem to be having problems in the commercialization phase? First of all, it is apparent that industry and academia do not work well together in the U.S. They don't seem to trust or understand each other. This may be only a problem of education, but I also think we need to introduce incentives that encourage a true partner relationship so that both parties win if technology is successfully transferred from academia to industry.

The interaction between industry and Government labs suffers from similar problems. I recently heard the comment that technology transfer is a body contact sport. Academic and National Lab researchers will have to get into the game side-by-side with their industrial counterparts if technology transfer is going to be really effective.

Major difficulties also arise when industry requires secrecy and/or exclusivity. This is required to have a chance to make an adequate return on investments in product and market development. Government policies and attitudes have discouraged secrecy and exclusivity, but some of these unproductive attitudes seem to be changing for the better.

For example, on an unsolicited basis we have been approached separately by the Los Alamos administration and by individual researchers to help them commercialize recent developments related to our product interests and to cooperate with our research work on high-temperature superconductivity. We are pursuing both of these prospects.

The second major problem is a gap in funding commercial efforts on technologies that have a long maturation. For example, venture capitalists normally invest only when there is a certain product that they judge to have good chances to generate large revenues and profits within a few years. They do not hang around for a decade waiting for development projects to mature, as may be the case for high-temperature superconductivity.

The Government's SBIR program is a great help to small companies to establish proof-of-principle or to build a prototype to attract venture or other capital, but it is too short-term for high-temperature superconductivity.

Large corporations also have difficulty justifying long-term R&D programs with uncertain pay-off. Perhaps only a dozen of the U.S.'s largest technology companies can afford to gamble millions of dollars per year for the next ten years as the wide-scale applications of high-temperature superconductivity emerge.

Finally, U.S. Government bureaucracy and politics can cause problems for small and large companies working on longer-term Government-sponsored technology development programs. BTI was lucky enough to be among the 200 original prime contractors selected from about 200 proposals for funding by DARPA's program to develop high-temperature superconducting processing and device technologies. But 11 months after submitting their application, nothing has happened. Red tape and budget politics have prevented the release of any money. In the meantime, we have, in good faith, spent $200,000 on equipment and $100,000 on salary and other expenses in an effort to make some progress in our project while the window of opportunity is still open.

The freeze on new R&D contracts announced last month by the Deputy Secretary of Defense Taft is close to the last straw. We will have real problems to keep the necessary personnel and equipment resources available for the project at our own expense much longer.

The Government could help best by establishing a consistent, predictable, long-term national commitment to superconductivity research and applications development. The following recommendations address the specific problems we have identified. First, provide long-term funding to encourage highly competitive basic research within academia and the National Labs in order to establish the scientific and engineering foundations of the technology. This must be coupled with incentives for technology transfer to industry, incentives to encourage close cooperation with industry's efforts to achieve commercial success. Industry partners should have the option for an exclusive license to the technology.

Second, enter into long-term superconductivity development contracts with both large and small companies to provide continuity of effort over several years as long as reasonable progress is demonstrated. The contractors should be offered exclusive commercial rights to all technical advances provided that a genuine effort is made to commercialize them.

Third, establish a new superconductivity SBIR program that provides for substantially more money over a longer term—for example, up to $2 million over four years instead of the current limit of one-half million dollars over two years.

And, fourth, create a significant tax incentive for large corporate expenditures on superconductivity research—for example, an unrestricted tax credit that would halve the nominal after-tax cost of superconductor R&D, including a 10-year carry-over provision. All costs of participation and consortium arrangements with other companies and with Government academic labs should qualify for this credit.

The key elements are continuity and predictability. Federal support of superconductivity R&D, both directly through grants and contracts and indirectly through tax incentives and policies to promote technology transfer, must be reliable over the long term.

Thank you.

[The prepared statement of Dr. Black follows:]

Testimony of

Dr. William C. Black, Jr.
Senior Vice President
Biomagnetic Technologies, Inc.
San Diego, California

at a hearing on

High Temperature Superconductivity Technology Transfer

before the

Subcommittee on Energy Research and Development
House Committee on Science, Space, and Technology

June 23, 1988

Thank you for the invitation to testify here today. My perspective on commercializing high temperature superconductivity is based on experience with a small company that has been manufacturing instruments with superconductor technology since 1970. Biomagnetic Technologies, Inc. (BTi) employs about 95 people. We anticipate product sales of $6.5 million for our fiscal year ending in September. BTi is widely recognized for accomplishments in commercializing superconductor technology. Until about four years ago we built specialized equipment sold mainly to low temperature physics laboratories. These products were truly state-of-the-art. In fact, Bednorz and Müller at IBM-Zurich delayed announcing their first discovery of high temperature superconductivity until after the crucial confirming measurements were made with an instrument they had just purchased from our company.

In 1984 we decided to reorient our business into an entirely new area with much greater growth potential. Using the superconductor technology we had perfected over the past decade, we had developed an instrument with the ability to examine disorders of brain function in an entirely new way—common disorders such as stroke, epilepsy, dyslexia, schizophrenia, and Alzheimer's disease. This new technique involves measuring the weak magnetic fields produced by brain electrical activity. It is known as magnetoencephalography, or MEG. MEG provides a sensitive, noninvasive means to track which parts of the brain are working at any given instant of time. This would be impossible without using extremely sensitive superconducting magnetic sensors. More than a dozen of the leading research institutions in the US, Western Europe, and recently in Japan have purchased our MEG system.

Importance of High Temperature Superconductivity to BTi

Our present products are based on conventional superconductors refrigerated by liquid helium. For research groups exploring the frontiers of how the brain works, the extraordinary new window on brain function provided by our instrument justifies raising funds to pay the $1 million price tag. Our goal over the next few years is to develop a cost-effective system for routine clinical use. While we believe we can do it with conventional superconductors, the requirements of liquid helium refrigeration present an engineering challenge that would be enormously simpler if we were able to operate the sensors even at liquid nitrogen temperature. With the right superconductor materials a lightweight helmet-like device could replace the current dual sensor units which weigh 100 pounds apiece and require elaborate, expensive gantries to position them around the head. We believe high temperature superconductors could have a tremendous impact on the size of our market by reducing the cost of the equipment and making it very much easier to use.

Government Supported R&D at BTi

BTi has received $1.8 million from the Small Business Innovation Research (SBIR) program. All of this support has been for projects directly related to our product development, and essentially all of it has come from the National Institutes of Health. Although the government has supported only a fraction of our total R&D expenditures over the past few years, it has had a disproportionately favorable impact. First, it enabled us to tackle some projects we could not otherwise have done, and fortunately they were very successful. Second, NIH support for our product ideas was a significant factor in raising two rounds of venture investment capital totalling over $10 million. Third, the SBIR program encouraged us to develop mutually beneficial

collaborations with university and government medical centers that have helped to steer our efforts in the right direction.

It is too early to tell whether or when high temperature superconductivity will be useful for our products. Therefore, we cannot put it in series with our product development plans over the next 3 to 5 years. On the other hand, high temperature superconductivity is potentially too valuable to be ignored, and we must be prepared to adopt it when possible to do so. But even though the potential benefits to our business may be clear, the cost and time to develop them is not. Since those key risk evaluation factors are not yet quantifiable, we could not afford to undertake a meaningful R&D effort in high temperature superconductivity without incremental outside funding specifically for this purpose. None of our previous government support has involved high temperature superconductivity research, but we have been notified of two awards in this area. Unfortunately, both of them are held up by a spending freeze at the Department of Defense resulting from a directive issued last month by the Deputy Secretary of Defense, William H. Taft IV.

Technology Commercialization

The Japanese and Europeans are much better equipped than the US to fund long term programs that have little or no commercial pay-off in the short term. They have a history of close government-industry cooperation that we do not share. In Japan, industry researchers work side-by-side with government researchers in the government labs to develop the base technologies and then take them back into their own product development process. This is a natural thing to do in Japan, but is highly unusual in the US. The Japanese also have an enormously strong formal and informal relationship between government, industry, and financial institutions that promotes a longer-term point of view. In the past, the Japanese have taken our basic

technology and applied superior product engineering and manufacturing skills to make cheaper, better products than the US. Superconductivity provides their first opportunity to develop a major technology from a position of commercial leadership at the start and they are showing every sign of a total commitment to dominate the future markets.

Commercialization is where our society stands to realize the benefits of this or any new technology—by expanding our economy and increasing our standard of living. Why do we seem to be having problems in the crucial commercialization phase?

First of all, it is apparent that industry and academia do not work well together in the US. They don't seem to trust or understand each other. This may be only a problem of education, but I also think we need to introduce incentives that encourage a true partner relationship so that both parties win if technology is successfully transferred from academia to industry. The interaction between industry and the government labs suffers from similar problems. I recently heard the comment that technology transfer is a body contact sport. Academic and national lab researchers will have to get into the game side-by-side with their industrial counterparts if technology transfer is going to be really effective. Major difficulties also arise when industry requires secrecy and/or exclusivity. This is required to have a chance to make an adequate return on investments in product and market development. Government polices and attitudes have discouraged secrecy and exclusivity.

Some of these unproductive attitudes seem to be changing for the better. For example, on an unsolicited basis, we have been approached separately by the administration and by individual researchers at Los Alamos to help them commercialize recent developments related to our product interests and to cooperate

with our research work on high temperature superconductivity. We are pursuing both of these prospects.

The second major problem area is a gap in funding commercial efforts on technologies that have a long maturation. For example, venture capitalists normally invest only when there is a certain product that they judge to have good chances to generate large revenues and profits within a few years. They do not hang around for a decade waiting for development projects to mature, as may be the case for high temperature superconductivity.

The government's SBIR program is a great help to small companies to establish proof of principle or to build a prototype to attract venture or other capital, but it is too short term for high temperature superconductivity.

Large corporations also have difficulty justifying long term R&D programs with uncertain payoff. Perhaps only a dozen of the US's largest technology companies (IBM, AT&T, Dupont, 3M, etc.) can afford to gamble millions of dollars per year for the next ten years as the wide-scale applications of high temperature superconductivity emerge.

Finally, US government bureaucracy and politics cause serious problems for small and large companies working on longer term government sponsored technology development programs. BTi was lucky enough to be among the original 21 prime contractors selected from about 200 proposals for funding by DARPA's program to develop high temperature superconductor processing and device technologies. But eleven months after submitting our application nothing has happened. Red tape and budget politics have prevented the release of any money. In the meantime, we have, in good faith, spent $200,000 on equipment and $100,000 on salary and other expenses in an effort to make some progress on our project while the window of

opportunity is still open. The freeze on new R&D contracts announced last month by Deputy Secretary of Defense Taft is close to the last straw. We will have real problems to keep the necessary personnel and equipment resources available for the project at our own expense much longer.

Recommendations

The government could help best by establishing a consistent, predictable, long term national commitment to superconductivity research and application development. The following recommendations address the specific problems we have identified:

- Provide long term funding to encourage highly competitive basic research within academia and the national labs in order to establish the scientific and engineering foundations of the technology. This must be coupled with incentives for technology transfer to industry, incentives to encourage close cooperation with industry's efforts to achieve commercial success. Industry partners should have the option for an exclusive license to the technology.

- Enter into long term superconductivity development contracts with both large and small companies to provide continuity of effort over several years as long as reasonable progress is demonstrated. The contractor should be offered exclusive commercial rights to all technical advances, provided that a genuine effort is made to commercialize them.

- Establish a new high temperature superconductivity SBIR program that provides for substantially more money over a longer term, for example, up to two million dollars over four years instead of the current limit of one-half million dollars over two years.

- Create a significant tax incentive for large corporate expenditures on high temperature superconductivity research, for example, an unrestricted tax credit that

would halve the nominal after-tax cost of superconductor R&D, including a ten-year carry-over provision. All costs of participation in consortium arrangements with other companies and with government/academic labs should qualify.

The key elements are continuity and predictability. Federal support of superconductivity R&D, both directly through grants and contracts and indirectly through tax incentives and policies to promote technology transfer, must be reliable over the long term.

Mrs. LLOYD. Thank you very much, Dr. Black.
Dr. Eror, please proceed.

STATEMENT OF DR. NICHOLAS G. EROR, PROFESSOR OF MATERIALS SCIENCE AND ENGINEERING, OREGON GRADUATE CENTER, BEAVERTON, OR, REPRESENTING MONOLITHIC SUPERCONDUCTORS, INC.

Dr. EROR. Thank you for the invitation to testify before the subcommittee today.

We've all been touched to some degree by the great advances in high-temperature superconductivity over the approximately last 18 months. In order for this excitement to be translated into substantive commercial development, there must be combined efforts in basic science, engineering, and manufacturing processing science. This important synergism was outlined in the report from the National Academies and the National Institutes of Health last year, and it called for the simultaneous implementation of basic science, engineering applications, and the manufacturing and processing sciences.

In a similar conclusion in a DARPA briefing also of last year, we pointed out that we needed to do things in a parallel fashion rather than the traditional series development which called for, first, research, then development, then design, then manufacturing, then leading on to prototype testing. This parallel development would implement all these elements together with feedback, weaving the important activities together. We simply cannot afford to do things in the traditional or current way.

As we reflect backwards, the Manhattan Project is, of course, an early and outstanding example of needed parallel developments. Some experts, however, in the current review process continue to hold to the serial development, calling, for example, for solution first to the critical current problem before further progress can be made in other areas.

The delays that have been outlined earlier today have been devastating both technically and personally. The original timetable, for example, called for 1987 DARPA funding in November. Delays in the budgetary process delayed this somewhat, although Congress should be commended for appropriating the $15 million for the DARPA program, particularly since the Administration did not request any such funding. DARPA is likewise to be commended for supplementing this appropriation with an additional $5 million.

As you well know, the DOD freeze which was implemented has delayed the implementation of the DARPA contracts. I'm delighted to hear of the progress that has been made in that direction and particularly the efforts of this Committee and the Members thereof to assure that this delay can be overcome in a very short amount of time.

There's been a very long time to attempt to exist without funding. For example, post-doctoral scientists that we have trained have had to take paid employment elsewhere. Important experiments have been postponed. Badly needed materials and supplies cannot be acquired. Even institutional reappointments are in jeopardy because of the failure to follow through on promised funding which

has been imminent for a very long time. One can carry on out of one's pocket only for a very limited amount of time.

The alternatives that we face, frankly, are to look offshore. We have a large number, indeed, a stack of inquiries from offshore organizations. We have placed all these on hold without any serious consideration being given to any of them, and I should mention also that the logo for Monolithic Superconductors uses the colors of red, white, and blue and includes the statement, "An American Company." We are committed to that goal, but we will not be able to sustain that commitment if further delays are incurred.

Diversity is called for in the program on high-temperature superconductivity. The new materials and their new sets of problems beg for the new approaches that have been discussed earlier. A recent draft report from the Office of Technology Assessment recommends the Government establish a commercial technology agency with an annual budget of about $100-$500 million to rate high-risk research and solve technical problems hindering U.S. efforts to commercialize new technology. This new agency would be modeled after DARPA, which was successfully created by DOD to explore the next generation of technology that might aid the military.

In keeping in mind the diversity that's required, it should be kept in mind that 18 months ago Paul Chu was on a terminal grant and on leave at NSF in part to explore other areas of research that might be more productive for him. The recent discovery of the highest-temperature superconductors using thallium were discovered by Professor Herman at the University of Arkansas. Even the work of Bednorz and Müller at IBM was carried out without the knowledge and blessing of management.

A diversity of efforts will be required for success, and it should be kept in mind that unless we make substantial investments in new technologies the required resources will not be available in the future for the very large expenditures that are appropriated.

We must get on with funding immediately by allowing DARPA to proceed by initiating its contracts. They should be strengthened by other funding as called for in the same report. This report called for $100 million in Fiscal Year 1988, and this was to be new funding and not reprogram money. This funding may take several forms and with participation of DOD and civilian agencies, and while the commercial technology agency is an excellent idea, we cannot afford to wait a year without additional funding for its establishment.

Nature abhors a vacuum, and the vacuum created by delay of our funding is not going unfilled. Early in 1987, we realized that if the critical current problems were solved with the new high-temperature superconductors several intrinsic problems remained. The new materials, of course, are ceramics and therefore have very little mechanical strength. In addition, they lose oxygen when heated and therefore lose their superconductivity, and when in contact with a base metal such as copper, the copper will deplete the oxygen from the superconductor, even at moderate temperatures with a concomitant loss in superconductivity, and the new high-temperature superconductors degrade in the presence of atmospheric water and carbon dioxide.

These processing problems could be overcome by consolidating the superconductors at room temperature with a shock wave which, at the same time, would laminate the superconductor within a metal matrix, all without reaction with the base metal, which will be needed, by the way, as a shunt in an actual real system, as we now currently use in the low-temperature materials. The process of shock consolidation thereby foregoes any subsequent required processing of the superconductor.

In summary, the ideal superconductor powder could be processed at room temperature without degrading the superconductor while, at the same time, putting it into what we refer to as an engineering and manufacturing environment.

I brought one of our early experiments with me which was carried out in the summer of 1987. This particular ring was fabricated by Northwest Technical Industries in Sequim, Washington, where we worked closely on the part of our organization. This ring represents a 40-fold increase in our first experiment. There's little over a pound of high-temperature superconductor in this ring with an outside dimension of superconductor of approximately 10 inches and an internal cross section of superconductor of nearly 2 square centimeters. This 40-fold scale-up was an experiment in determining how easy that would be to scale, and this could, indeed, be scaled up to be several feet in diameter or tens of feet very easily.

We have published our early results, in fact, early on, and first publication was last September in *Nature*. We followed that with other publications describing the microstructure of the materials that we created. We've been limited in these follow-on studies because we have not had the funding to undertake the important experiments in shock consolidation that need to be done.

Los Alamos National Laboratory has been willing to be cooperative with us, but we have been unable to fabricate further structures for testing and optimization. Los Alamos has been able to carry out some of their own studies in shock consolidation with their own internal funding. My understanding is that they have some extramural funds as well at this time.

Lawrence Livermore National Laboratory has also received funding through DOD to investigate shock consolidation of high-temperature superconductors. Unfortunately, the delay in the funding which has been devastating, as outlined above, has also resulted in placing us on the sidelines while other players enter the game. We need to get under way and contribute now in a major way to the commercialization of high-temperature superconductivity.

Thank you.

Mrs. LLOYD. Thank you very much.

[The prepared statement of Dr. Eror follows:]

Testimony of Nicholas G. Eror
Professor of Materials Science and Engineering
Oregon Graduate Center
and Representing
Monolithic Superconductors, Inc.

Before The Subcommitte on Energy, Research and Development of the Committee on Science, Space and Technology
U.S. House of Representatives
Hearing on
High Temperature Superconductivity Technology Transfer
Thursday 23 June 1988

Madam Chairman and Members of the Subcommittee

Thank you for the invitation to speak before the Subcommittee today. We have all been touched to some degree with the exciting developments in high-temperature superconductivity that have taken place so dramatically over the last 18 months. In order for this excitement to be translated into substantive commercial development there must be combined efforts in basic science, engineering and manufacturing/processing science.

This important synergism was outlined in the Report of the Research Briefing Panel on High-Temperature Superconductivity. This report called for the simultaneous implimentation of basic science, engineering applications and manufacturing/processing science. In a similar conclusion the DARPA briefing on Processing, Fabrication and Demonstration of High Temperture Ceramic Superconducters stated that the old model of a series development of research - development - design - manufacturing - prototype testing needed to be replaced by a parallel development of these elements with feedback weaving these important activities together. We simply cannot continue to do things in the traditional or current way. The Manhatten project is, of course, an outstanding example of the needed parallel developments. Some "experts" in the review process continue to call for a serial development of problem solving before research is committed to the development through prototype testing steps.

The delays have been devastating both technically and personally. The original time table called for November 1987 DARPA funding. Delays in the bugetary process postponed this somewhat, although Congress should be commended for appropriating the $15 million for the DARPA program since none was requested by the administration. DARPA is likewise to be commended for supplementing this appropriation with $5 million of their own redirected funds.

As you well know we are currently under a DOD freeze which has delayed the implementation of the DARPA program. I have cancelled my second trip to Washington to participate in the DARPA kick-off meeting (April and June). It has been a very long time to attempt to exist without funding. Post-doctoral scientists that we trained have had to leave to take paid employment elsewhere. Important experiments have been postponed. Badly needed materials and supplies cannot be acquired. Institutional reappointments are in jeopardy because of the failure to follow through on promised funding that have been imminent for a very long time. One can only carry on for so long out of one's own pocket.

The alternative that we face is to look off-shore. We have a very large number--indeed, a stack, of inquiries from off-shore organizations. We have placed all of these on hold without serious consideration being given to them. I should mention that the logo for Monolithic Superconducters uses the colors of red, white and blue and includes the statement--An American Company. We will not be able to sustain this committment and desire if further delays are incurred.

Diversity is called for in the program on high temperture superconductivity. The new materials and their new set of problems begs for new approaches as discussed earlier. The draft report by the Office of Technology Assessment recommends that the government establisn a Commercial Technology Agency with an annual budget between $100 and $500 million to aid high-risk research and solve technical problems hindering U.S. efforts to commercialize new technology. This new agency would be modeled after DARPA which was successfully created by DOD to explore the nest generation of technology that might aid the military.

It should be kept in mind that just over 18 months ago that Paul Chu was on a terminal grant and was on leave at NSF, in part, to survey other more productive areas of research in which he might be involved. The recent discovery of the highest temperature superconductors using thallium came from Professor A. M. Hermann at the University of Arkansas. Even the work by Bednorz and Muller at IBM was carried out without the knowledge or blessing of management. A diversity of efforts will be required for success.

We should remember that without substantial investments the required resources will not be available in the future for the very large expenditures that are appropriated.

We must get on with the funding immediately by allowing DARPA to proceed by initiating its contracts. This should be strengthened by other funding as called for in the report from the National Academies of Science and Engineering, and Institutes of Health (Report of the Research Briefing Panel on High-Temperature Superconductivity) which called for $100 million of new funding (not reprogrammed money) for FY 1988. This funding may take several forms with the participation of DOD and civilian agencies. While a Commercial Technology Agency is an excellent idea, We cannot afford to wait a year, without additional funding, for its establishment.

Nature abhors a vacuum and the vacuum created with the delay of our funding is not going unfilled. Early in 1987 we realized that if the critical current problem were solved with the new high temperature superconductors, several intrinsic problems remained. The new materials are ceramics and, therefore, have very little mechanical strength; they loose oxygen when heated and, therefore, loose their superconductivity; when in contact with a base metal such as copper, the copper will deplete oxygen from the superconductor (even at moderate temperatures) with a concomitant loss of superconductivity; and the new high temperature superconductors degrade in the presence of atmospheric water and carbon dioxide. These processing problems could be overcome by consolidating the superconductors at room temperature with a shock wave which at the same time, laminated the superconductor within a base metal matrix for mechanical strength and protection from the degrading ambient environment--all without reaction with the base metal (which will be needed as a shunt if supperconductivity were to be lost) and without degradation of the superconductivity. This process of shock consolidation thereby foregoes any subsequent required processing of the superconductor. In summary, the ideal superconductor powder could be processsed at room temperature without degrading the superconductor while at the same time putting it into what we call an engineering and manufacturing environment.

I have brought one of early experiments carried out during the summer of 1987 and first published in Nature on 4 September 1987. This ring represents a 40-fold scale-up of our first experiment and contains over a pound of Y-Ba-Cu-O superconductor in ring form with an outer superconductor diameter of 10 inches and a cross section of nearly two square centimeters. This structure can easily be scaled-up again to a size of several feet in diameter.

We have published our early results and have followed this with other publications describing the microstructures that have been created. We have been limited to these follow-on studies because of the lack of funding to proceed with further important experiments in shock consolidation.

Los Alamos National Laboratory has been willing to be cooperative with us but we have not been able to fabricate further structures for testing and optimization. Los Alamos has been able to carry out some of their own studies in shock consolidation of high temperature superconductors with internal funds and my understanding is that they have received DARPA funding through the DOE office at Sandia Laboratory in Albuquerque.

Lawerence Livermore Laboratory has also received funding--through DOE, to investigate shock consolidation of high temperature superconductors.

Unfortunately, the delay in our funding which has been devastating as outlined above, has also resulted in placing us on the sidelines while other players enter the game. We need to get underway and contribute in a major way to the commercialization of high temperature superconductivity.

Mrs. LLOYD. Mr. Lloyd.

STATEMENT OF JERRY D. LLOYD MANAGER ADVANCED MOTOR DEVELOPMENT, EMERSON ELECTRIC CO., HAZELWOOD, MO

Mr. LLOYD. Thank you, Madam Chairman.

I'm the manager of the Advanced Motor Development Center of Emerson Electric, which is located in St. Louis. Emerson welcomes this opportunity to talk before this Committee. We are a major manufacturer of a wide variety of both defense and commercial products. Our facilities are located world-wide.

Emerson has some 55 divisions and manufacturers components in some 111 facilities. Emerson Motor Company is one of America's leading manufacturers of factional and integral horsepower motors and variable speed motor drives. The Emerson Motor Company comprises six operating divisions of Emerson Electric: the Appliance/Hermetic Division, which manufactures fractional horsepower motors for use in major appliances; a Specialty Motor Division, which manufactures fractional motors in a wide variety of residential applications; the U.S. Electrical Motor Division, which manufactures integral horsepower motors that are used in a wide number of commercial and industrial applications; we have an Industrial Controls Division, which produces electronic adjustable speed drives; an Electronic Speed Control Division, which produces small AC drives for light commercial and residential nature; and we have an Industrial Service Division, which is essentially a service center for motor repair.

Emerson Motor Company employs in excess of 10,000 people world-wide. Production is in 11 of the continental United States, and we also have some facilities in Brazil, Japan, Mexico, and Canada.

The Motor Company's research and development spending amounts to millions of dollars each year. In April, 1988, ground was broken on the construction of a new engineering center in St. Louis which, upon completion in the summer of 1989, will rank among the largest and most sophisticated motor and drive research and development centers in the world. This facility will house more than 400 engineers and technicians from the various operating divisions and will include space dedicated to the development and testing of superconductivity motors.

Another division, the Electronic Space Division, is engaged in various military and defense applications. This division has been in the Government and defense business for over 40 years.

Because of these factors, we believe our perspective provides unique insight on superconductivity national investment strategy in this area and the exploitation of advances that will contribute to regaining international competitive positions in the marketplace.

The benefits of superconductivity will accrue to the U.S. if its exploitation and advancement result from a bold commitment to a position of national technical leadership driven by the concurrent demands of both the commercial and the military uses.

National technical leadership, in turn, demands a long-term investment strategy and priority of objectives focused by the sustained public vision and long-term goals capable of surviving the

inevitable short-term realities created by our current national resource constraints.

Today, superconductivity is unlike the nationwide commitment to place a man on the moon. Then the Nation was asked to commit to a public vision of a final outcome clearly articulated and easily recognized when accomplished. Applications of existing scientific and technological gains were required, and others followed. Now our breakthrough in science and its associated technologies beg for a similar vision. Unlike the past, the breakthrough and the means to exploit it no longer reside essentially within our borders. Superconductivity is an international science and technology competition to establish a basis for long-term applications.

The advanced motor development group of the Emerson Motor Company is responsible for the research and motor technology and to assess the impact new technologies will have on the product lines of the company.

We are presently involved in many programs in the domestic appliance market related to energy conservation. Some of our major programs include variable capacity heat pump systems, variable speed blowers for gas furnaces, air conditioners, spa pumps, and washing machine drives. All of these appliances consume a considerable amount of energy.

Of the domestic products mentioned, air conditioning is perhaps the largest user. We are presently developing products for this market using some of the newer motor technologies and have identified designs that can reduce motor losses by as much as 36 percent. Of the remaining losses in the motor, 50 percent are winding losses, most of which could be eliminated if we had a superconductive material in the windings.

Superconductivity wire would also affect the size and weight of the design, allowing us to reduce the size of a given motor by as much as 40 percent. All of this is not feasible unless we can develop an economical high-temperature superconductor wire. Many of the applications will require even higher temperatures than those that have been confirmed to be producible. The present materials are in the 90 degree Kelvin range. This is not a very practical temperature for most commercial uses.

Processes need to be developed to economically produce the raw materials and fabricate them into wires that can be manufactured in the motors. Methods need to be developed to connect the superconductor to the utilities. Superconductor materials currently being evaluated are very brittle, thus making them difficult to handle. They are reactive to most environments, which means new protection methods need to be developed and new conduction means invented.

In a nutshell, this technology has great potential, but it is only in its infancy and will require a considerable amount of research to bring it to commercialization.

Emerson has been following the superconductivity technology and doing some limited assessment of how this technology could affect our business. Currently, the technology is too high risk to warrant Emerson investing considerable amounts of money into the research of this technology at this time. The materials are very

expensive and still relatively low temperature and are not available in a usable form.

The opportunity of working in this new and exciting technology through the Government-funded DARPA contract was very appealing to Emerson when we were approached by Ceramic Process Systems, a prime contractor for the superconductor project that was accepted by DARPA. High risks with high payoffs characterized the endeavor. The activity is high risk because the processes of material synthesis, wire fabrication, motor fabrication, and assembly are new and untested in the marketplace. The program is high payoff because entirely new product concepts and many old applications are affected by successful advances.

Our Government and Defense Group sees much possibility for high payoff from the successful production of superconductivity materials fabricated in thin and thick films as well as wire. The value of a national investment in a high-risk superconductivity advances resulting in a military advantage seems clear.

What then is the solution? Government involvement should assure availability of funds and interagency coordination that first permits and then enables the simultaneous investment of high-risk and high-payoff applications derived from the technology requirement arising from both the needs of the military and the needs of the U.S. industrial base for commercial applications.

Superconductivity is an area of investment for Emerson Electric that illustrates many of the difficulties associated with strategic research and development management and the alignment of business strategies and objectives with national strategies and objectives. Superconductivity is a science and technology in which goal setting must take place in a fast-changing environment.

At the present time, the financial community has no incentive for rewarding the industrial company for long-term R&D that guarantees corporate long-term survivability. The financial community rewards those companies who pay attention to the short term. Translated simply, this means without near-term Government contracts to support the high risk, no matter whether they are high pay-off opportunities, must be evident and must be captured by those companies who wish to receive favorable financial community reporting.

Applying for the DARPA contract was straightforward and went quite smoothly. We had adequate time to prepare a proposal, and the initial phase went very well. After the initial screening, we had to submit an addendum to the proposal which went into more detail on the project. Here again, we were given adequate time to respond and sufficient information to reply to DARPA's request.

At this point is where the problems began to arise in the form of waiting. Our proposal was submitted on July 22, 1987, and the addendum on October 27, 1987. We were told in January that the proposal was approved, but as of this date we still have not received written approval or been granted any funding.

Emerson and the other researchers in this program cannot justify committing large resources to this high-risk technology. The longer the Government delays in funding this type of research, the more advantage offshore countries will have. We believe this technology offers clear benefits to this country in the form of reduced

energy consumption and improved defense and sincerely hope the Government will lift its freeze on the funding of these projects so our country can maintain its status as a technological leader.

Thank you.

[The prepared statement of Mr. Lloyd follows:]

TESTIMONY

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

June 23, 1988

Jerry D. Lloyd

Manager, Advanced Motor Development

Emerson Electric Co.

Good Morning. My name is Jerry Lloyd. I am the Manager of the Advanced Motor Development Center at Emerson Electric Co. Emerson welcomes the opportunity to come before this committee. We are a major manufacturer of a wide variety of both defense and commercial products. Our facilities are located world-wide.

The Emerson Motor Company is one of America's leading manufacturers of fractional and integral horsepower motors and variable speed motor drives. The Motor Company comprises six operating divisions of Emerson Electric Co.

- o Appliance/Hermetic Motor Division, which manufacturers fractional horsepower motors for use in major appliances (washers, dryers, dishwashers and compactors) and both fractional and integral horsepower rotor stator sets for use in hermetic and semi-hermetic compressors (air-conditioning and refrigeration).
- o Specialty Motor Division, which manufacturers fractional and sub-fractional motors used in a variety of commercial and residential applications including:
  - Fan and blower motors (residential air-movement),
  - Pump motors (sump pumps, spas, whirlpools, etc.),
  - Air-compressor motors (diaphragm compressors),
  - Business-equipment motors (electronic output devices, disk-drive blowers, etc.),
  - Right angle and parallel shaft gear motors (hospital beds, reclining chairs, etc.).
- o U.S. Electrical Motors (USEM), a producer of integral horsepower motors and mechanical, electro-mechanical and electrical adjustable-speed drives. USEM's motors include both vertical and horizontal designs, NEMA and larger horsepower ratings, and are used in a wide number of commercial and industrial applications:

- Industrial, municipal and agricultural pumping and liquid-handling,
- Industrial process machinery (conveyor systems, material handling equipment, hoists and cranes, etc.),
- Commercial and industrial HVAC equipment (high-volume air-movement).

o Industrial Controls Division (ICD), which produces electronic adjustable-frequency motor drives (continuous modulation) of motor shaft speed based on sensor, timer, programmable logic or human input). ICD's products, both AC and DC, are primarily integral horsepower, covering substantially the same power range as USEM's motors and sold to substantially the same markets/applications.

o Electronic Speed Control Division, a manufacturer of adjustable-frequency AC motor drives used in variable speed applications of a primarily light commercial or residential nature:
- Compressors,
- Blowers and fans,
- Pumps,
- Appliances.

o Industrial Service Division, a network of service centers specializing in:
- Motor repair, rewind and refurbishment,
- Transformer repair,
- Predictive maintenance service for customers' rotating machinery,
- On site total motor management services encompassing predictive maintenance, downtime scheduling, stock rotation and motor repair.

The Motor Company's products are sold under a broad array of brand names, both own-make and private label. The Company's customer base extends to nearly all North American producers/users of the products/applications enumerated above, and extends to a nation wide network of aftermarket wholesalers/distributors. A not inconsiderable proportion of the Company's annual revenue is realized in markets outside of North America.

The Motor Company employs in excess of 10,000 people worldwide. Production spans the globe from Brazil to Japan to Canada, Mexico and 11 of the continental United States. The company's manufacturing profile is one of the comparatively high value-added: processes extend from the initial slitting of steel coil for use in the motor laminations all the way through delivery of the motor to the customer's receiving docks.

The Company's business philosophy is that of its parent, Emerson Electric Co.:

- o A commitment to quality and serving the customer.
- o A commitment to being the global best-cost producer in each of its product lines (lowest unit production cost commensurate with the technology, sophistication and function of the product in question).
- o A commitment to Research and Development Spending and New Product Development.
- o A commitment to capital expenditure for cost-reduction and productivity.
- o A commitment to the global marketplace.

The Motor Company's Research and Development spending amounts to millions of dollars each year. In April 1988, ground was broken for the construction of a new Engineering Center in St. Louis which, upon completion in the summer of

1989, will rank among the largest and most sophisticated motor and drive Research and Development Centers in the world. This facility will house more than 400 engineers and technicians from the various operating divisions, and will include space dedicated to the development and testing of superconductive motors.

o The Electronic Space Division (ESD) is engaged in various military and defense applications. ESD has been in the government and defense business for over 40 years and specializes in the following related products and systems:

- Radar systems,
- Guidance and control systems,
- Telemetry tracking systems,
- Automatic test equipment,
- Airborne, ground, and surface armament systems,
- Special tactical vehicles.

Because of these factors, we believe our perspective provides unique insight on superconductivity, national investment strategy in this area, and exploitation of advances that will contribute to regaining international competitive positions in the marketplace. As a result, much is written on the potential of superconductivity. Time constraints preclude all but reference to these potentials. Instead, our testimony today addresses a more compelling issue - national technical leadership.

The benefits of superconductivity will accrue to the U.S. if its exploitation and advancement result from a bold commitment to a position of national technical leadership driven by the concurrent demands for both commercial and

military uses. National technical leadership, in turn, demands a long-term investment strategy and priority of objectives focused by a sustaining public vision and long-range goals capable of surviving the inevitable short-term realities created by our current national resource constraints. Today, superconductivity is unlike the nation-wide commitment to place a man on the moon. Then, the nation was asked to commit to a public vision of a final outcome - clearly articulated and easily recognized when accomplished. Application of existing scientific and technological gains were required; and others followed. Now, a breakthrough in science and its associated technologies beg for a similar vision. Unlike the past, the breakthrough and the means to exploit it no longer reside essentially within our borders. Superconductivity is an international science and technology competition to establish a basis for long term applications.

Although U.S. R&D excels in producing the substance of scientific and technological advancements, we underestimate the difficulties of achieving commercial products from our inventory and capacity to produce scientific and technical results. U.S. industry competes well when the product is defined and the processes of production exist. In these cases, incremental improvements are possible, economic payoffs are more frequent, and technical risks are minimized. For the nation to realize the benefits and potentials of superconductivity, we should recognize that high utility product concepts and economic manufacturing processes must exist before profitable and competitive businesses can be established. During this phase of scientific and technological maturation, visionary leadership, investment priority, and steady commitment to a national direction play a crucial role in nurturing this scientific and technological curiosity to a commercializable state suitable for industrial exploitation.

The Advanced Motor Development Group of Emerson Motor Company is responsible for the research in motor technology and to asses the impact new technologies will have on the product lines of the company.

We are presently involved in many programs in the domestic appliance market related to energy conservation. Some of our major programs include variable capacity heat pump systems, variable speed blowers for gas furnaces, room air conditioners, spa pumps and washing machine drives. All of these appliances consume a considerable amount of energy.

Of the domestic products mentioned, air conditioning is perhaps the largest user, whether it be for heat generation or cooling since most homes in the USA need to be heated, cooled or both. We are presently developing products for this market using some of the newer motor technologies. For example, we are developing brushless permanent magnet motors for the hermetic compressor which will improve the motor efficiency from 86 percent to 91 percent. This represents a reduction in motor losses of 36 percent. Of the 9 percent losses remaining in the motor, 50 percent are winding losses, which could be eliminated if we had a superconductor material in the windings.

Superconductive wire would also effect the size of the design allowing us to design motors with more output from a given volume, i.e. high power densities. Based on some preliminary analysis, we may be able to reduce the size of a given motor by 40 percent with superconductive wire.

All of this is not feasible unless we can develop an economical high temperature superconductor wire. Many of the applications will require even higher temperature materials than those which have been confirmed to be producible. The present materials are in the 90°K range. This is not a very

practical temperature for most commercial uses and for this technology to make the US a technology leader, it will require a room temperature material and there are indications that a material such as this may be possible.

Processes also need to be developed to economically produce the raw materials and fabricate them into wires that can be manufactured into motors. Methods need to be developed to connect the superconductor to the utilities.

Superconductor materials currently being evaluated are very brittle, thus making them difficult to handle, they are reactive to most environments which means new protection methods need to be developed and new connection devices invented.

In a nut shell this technology has great potential but is is only in its infancy and will require a considerable amount of research to bring it to commercialization.

Emerson has been following the superconductive technology and doing some limited assessment of how this technology could effect our business. Currently, the technology is too high-risk to warrant Emerson investing considerable amounts of this money into the research of technology at this time. The materials are very expensive are still relatively low temperature and are not available in a usable form.

The opportunity of working on this new and exciting technology, through a government funded DARPA contract was very appealing to Emerson when we were approached by Ceramics Process Systems, the prime contractor for the superconductor project that was accepted by DARPA.

Ceramic Processing Systems Superconductor, Inc. engaged Emerson Electric Co.'s Motor Division as part of a DARPA funded R&D program to apply the superconducting wire fabricated by CPSS for the fabrication of motors. High-risk with high payoffs characterize the endeavor. The activity is high risk because of processes of material synthesis, wire fabrication, motor fabrication and assembly are new and untested by the market places. The program is high payoff because entirely new product concepts and many old applications are affected by successful advances. Our Government and Defense Group sees much possibility for high payoff from the successful production of superconductive materials fabricated as thin and thick films, as well as wire. The value of a national investment in high-risk superconductive advances, resulting in military advantage, seems clear. The commitment grows for defense applications. The maintenance of adequate investment and the creation of a driving public vision for the commercial use and subsequent economic benefits yet to come from applied superconductivity remains the challenge for government. Although superconductivity is in its infancy, but growing and maturing very rapidly, our national success depends on national technical leadership that actively and boldly engages and mobilizes government, industry and academia to achieve the individual and corporate successes necessary, but not sufficient to ensure that the U.S. receives full benefits from our scientific and technological strengths.

What then is the solution? Government involvement should assure availability of funds and interagency coordination that first permits and then enables the simultaneous investment in high-risk and high-payoff applications derived from technology requirements arising from both the needs of the military and the needs of the U.S. industrial base for commercial applications. This is not an

either/or challenge. Defense applications do indeed have unique military requirements that constrain the application of expected advances in both time and performance. Similarly, the economic security of the U.S. depends substantially upon the health and well-being of free enterprise and the U.S. industrial base for achieving commercial application successes. The commercial pursuit of superconductivity is likewise high risk, but with high payoff. Perhaps a public vision of reduced energy dependence by improved energy efficiency resulting in energy security could serve as a vision. Perhaps successful use of superconductive products in the transportation industry could be another. In any case, the commercial sector depends substantially upon the ability of industry to embed the technology in products that are exportable and, thereby, capable of having an effect on our balance of trade. There is little doubt that this singular scientific advance and its associated technologies will have significant effects on both military and commercial applications. There should also be no doubt of its relevance to both sectors.

How does superconductivity R&D fit into our business and research plans? Superconductivity is an area of investment for Emerson Electric that illustrates many of the difficulties associated with strategic research and development management and the alignment of business strategies and objectives with national strategies and objectives. Superconductivity is a science and technology in which goal setting must take place in a fast changing environment. The factors which alter this environment effect industry in a variety of ways. Superconductivity is an area of research and development in which the pace of change demands a combination of both incremental improvement of an old product with the simultaneous introduction of a new product. In this

case, old product is relatively new itself and rapidly ages only because of the rapid rate of change in the underlying scientific advances and technological advances that support its exploitation. This creates a very tight coupling of new technology for new products with old technology and old product. This has the effect of confusing the fundamental differences between the management activity that introduces new technology or new products from the introduction or incremental improvement of old product. The critical issues is not whether or not the U.S. science and technology base can be or remain competitive in the production of new knowledge and technical means for exploiting that knowledge, nor does it mean that the U.S. lacks competitiveness in the introduction of new product, nor lack of competitiveness in the improvement of old product, for incremental improvement is where most competition occurs and the U.S. has demonstrated a substantial capability for a tight coupling of development and manufacturing and achieving the subsequent competitive position second to none. Superconductivity is a major advance in both science, technology and its coupling with development and manufacturing at an unprecedented pace, therefore, creating unprecedented management problems for businesses and researchers attempting to cross the bridge from scientific and technical advance to development and manufacturing exploitation and, in return, take back, in the form of feedback, the problems discovered in the development and manufacturing phases and market introduction phases to the scientific and technical community. Thus, any one involved in superconductivity R&D and the business of exploiting those advances must deal with the broadest range of management issues of both strategic importance and day-to-day operational impact. From this prospective, superconductivity R&D does not fit, in a

classical sense, into the normative definition, development, conduct and management of a research plan directed toward a business end. However, we do not feel that this problem in insurmountable, nor outside the scope of normative research planning and business planning, but rather demands a much more flexible, fast-paced and knowledgable management for the conduct of science and technology and its transition through innovation to the marketplace.

In this respect, superconductivity R&D is no different than other R&D. We must focus by getting our R&D strategies right. We must set priorities and watch for surprise. We must manage the transition of R&D results into useful applications desired by the marketplace. The purpose of our R&D is to produce change. It is affected by and causes external change. Users are involved in setting the bounds on our research agenda, because they ultimately form the marketplace, and we will meet them in the marketplace even earlier than history would teach us. However, details of execution are left to the performer, and our business units fund development of our new products. However, there is one area of concern. This area of concern is process. Because of this rapid pace of change in the scientific and technical foundation that feeds the development and manufacturing of new product and incremental improvement of the old product, the U.S. industrial bias toward what we make and not how we make it must alter. Rapid scientific and technical advance in superconductivity must be accompanied by equally rapid scientific and technical advance in the prescriptions for "how to" develop and manufacture the product that will go to the marketplace. In this respect, superconductivity R&D is not a normative fit. Incremental improvement for the introduction of a new product or

improvement to an old product generally is accompanied by incremental improvement or addition of process technology and underlying scientific knowledge to support that process change. Superconductivity is not accompanied with an existing basis of process from which to prescribe the "how to" or to assure the "know how" exists for the successful competitive production of products based on superconductivity scientific and technical advance. Although substantial opportunity exists to succeed in the endeavor from superconductivity R&D to its embodiment as a salable product, many financial risks exist. The risks result because of an inability to assure ones self that major marketplace objectives exist for a long enough duration to justify the investment, even though the investment may occur over a much shorter product and process life cycle. Thus, the difficulty becomes one of selection of direction with sufficient stability to enable industrial investment in achieving the goals of that direction that assure a reasonable return to justify the effort required to manage an R&D program to successful conclusions. The issue is less one of the duration of the marketplace than the assurance, from a planning prospective, that potential multiple failures will not adversely effect the achievement of some success of sufficient payoff to warrant continued investment in the many varieties of opportunities and directions superconductivity presents.

The problems and opportunities in superconductivity projects and associated processes do, in fact, offer many opportunities to enhance our tech base and improve our business posture for the future. Four major areas of concern present themselves. One is vision. There must be a national vision of the potential benefits to be derived from the application and use of

superconducting products. Vision is a classical top-down approach to characterizing a future the nation desires. Second, is requirements. There must be a clear articulation of potential or actual product requirements to bound and guide the application of national science and technology assets to create a comparative reason for the successful achievement of the vision. Third, there must be mechanisms for rapid scientific and technology advance, often referred to as technology push, to easily and quickly bridge the boundary between science and technology and engineering development and manufacturing of product, and that transition must include a corresponding feedback that permits the problems of associated downstream innovation to be communicated rapidly to the upstream activity seeking to produce change. And third, the environment that surrounds the characterization and articulation of the vision, the sense of requirement demand and the ability to rapidly change and supply the scientific and technical environment is a critical issue. It must be conducive to national technical leadership, development of a vision for the nation for individual business units. It must not impede the concept development necessary to drive and create the requirements that pull on the industrial base to develop specific products and to improve on those products. And finally, that environment must enable technology push that is the bold and aggressive suit of innovation that captures and packages the rapid scientific and technical advances in superconductivity and transitions them to a new product significantly different from the old product. If there were a single problem that superconductivity might serve as a catalyst for change, it would be that of long-term incentive. At the current time, the financial community has no incentive for rewarding an industrial company for long-term R&D that guarantees

corporate long-term survivability. The financial community rewards those companies who pay attention to the short-term. Translated simply, this means, without near-term government contract to support and fund high-risk, no matter whether they are high payoff opportunities, must be evident and must be captured by those companies who wish to receive favorable financial community reporting. Let there be no mistake, there is no incentive for considering a short-term or near-term contract to conduct a long-term activity.

Major Points:

- o The maturity of superconductivity science and technology demands a government role for the research and development of high risk, high payoff commercialization. The issue is what role should that be.
- o The U.S. does not have a non-defense initiative with a mission to create and prevent scientific and technological surprise and assure commercial exploitation of such advances, with the objective of ultimately returning to a state of economic security by achieving such goals as energy efficiency and products that improve international balance of trade.
- o The defense science and technology infrastructure has an agency (DARPA) with a mission to advance and exploit high-risk, high-pay-off science and technology for military application. Clearly, success at this endeavor creates advances that, if released for commercialization before successful application and use for military advantage, could lead to both loss of defense security, as well as early exploitation by competing economic interests around the world.

- Conversely, if the nation could mobilize national industrial resources to achieve the equivalent purpose of advancing science and technology for high risk, high-pay-off commercialization, some form of focused national effort is required that assures national technical leadership, coordinated interchange among both defense and non-defense R&D agencies, and established priority for the use of national assets and allocation of funds toward the long-term achievement of both commercial and military success. Our government and defense group companies are capable of competing for funding to pursue high-risk, high-pay-off activities within the defense sector. For example, indeed the superconductivity funding associated with the Emerson subcontract to CPSS for the development of a superconducting motor represents a high-risk, high-pay-off advance and application of superconducting technology. However, a non-defense initiative does not exist. Clearly, application and use of these technology advances should rightfully be directed at gaining national security in the form of military advantage. To the extent that these technologies do not become militarily critical and they can be embodied in commercial product capable of being sold abroad, these advances will result in balance of trade impacts and consequent national technical leadership in areas demanding energy efficiency. The government's role is to finance the activity in a way the industrial sector can exploit them without giving up its rights to bring them to commercialization.

Applying for the DARPA contract was straight forward and went quite smoothly. We had adequate time to prepare our proposal and the initial phase went very well.

After the initial screening we had to submit an addem to the proposal which went into more detail of the project. Here again, we were given adequate time to respond and sufficient information to reply to DARPA's request.

After this point is where the problems began to arise in the form of waiting. Our proposal was submitted on July 22, 1987, and the addendum on October 27, 1988. As of this date we still have not received written approval or been granted any funding.

Emerson and the other researchers in this program cannot justify committing larger resources in this high risk technology. The longer the government delays in funding this type of research the more advantage offshore countries will have.

We believe this technology offers clear benefits to this country in the form of reduced energy consumption and improved defense and sincerely hope the government will lift its freeze on the funding of these projects so our country can maintain its status as a technological leader.

SUMMARY

1. Superconductivity is one example of major science and technology advances occurring at a rate that demands equally rapid engineering development and manufacturing advances, if the nation commits to acquiring the promised benefits and desired economic results perceived for superconducting products.
2. The challenge is to integrate U.S. scientific and technological strength with U.S. industrial development and manufacturing strength to regain the lead in economic competitiveness. Sustained R&D competitiveness and market developments require tight coupling of national vision; the "pull" of market needs; the "push" of technology; and a supportive investment environment for the long-term as well as the near-term.
3. National technical leadership must cause to change the disincentives that prevent a smooth transition to an integrated strategic management of R&D investment that produces the necessary science and technology advances concurrent with sufficient engineering and manufacturing developments. Superconductivity is one of the many breakthrough in our national future that provide a learning opportunity for bridging the gap between world class science and technology competitiveness and worldclass excellence in engineering and manufacturing competitiveness.
4. The solution involves government, industry and academia in cooperative long-term commitments and short-term individual, corporate, and government agency execution accountability. Successful integration of our national competitive strengths to regain economic strength demands national strategy, national investment and unprecedented strategic management skills from the nation's leadership.

Mrs. LLOYD. Thank you very much, Mr. Lloyd.
Mr. Conrad.

STATEMENT OF DAVID CONRAD, MANAGER OF RESEARCH AND TECHNOLOGY, ALLIED-SIGNAL AEROSPACE CO.

Mr. CONRAD. Thank you, Madam Chairman.

I'm Dave Conrad, Manager of Research and Technology for Allied-Signal Aerospace. To orient those who may be unfamiliar with the name Allied-Signal Aerospace, it was formed in 1987, in January—pardon me—January of 1988, by the merger of the Garrett Corporation and Bendix Aerospace.

I'm pleased to appear before this Subcommittee on behalf of Allied-Signal Aerospace to discuss superconductivity and its impact on the industrial base. We appreciate the continued interest of the Subcommittee in what we feel to be a critical technology for the United States.

High-temperature superconductors have become an issue of national pride, and some people say it is a test of whether the United States can compete in a world of high technology. On July 28 and 29, 1987, the Department of Energy, assisted by the Department of Defense and the Department of Commerce, held the Federal conference on the commercial applications of superconductivity. At this conference, President Reagan announced an 11-point initiative to support superconductivity and the desire to make the technology development a national priority and to win the global race.

Right now, we're a year later from that announcement, and various other speakers this morning have highlighted kind of the status of where we are, but I would like to bring up two points. First, a great deal of money has been spent on basic research but very little on the manufacturing technology necessary to bring high-temperature superconductors to the commercial market. Secondly, very little effort has been expended on the one system needed to make high-temperature superconductors a practical reality—that is, cryogenics.

Traditionally, our involvement with this technology has been as a manufacturer using superconducting materials. AiResearch, Los Angeles Division, for example, has used superconducting niobium titanium wire to wind a 3,000 horsepower motor which was delivered to the U.S. Navy's David Taylor Research Center in 1980.

Our perspective on high-temperature superconductors has changed some from this manufacturing viewpoint. Today, within Allied-Signal, we have put together the type of team we feel is essential to commercializing high-temperature superconductors. This team consists of the scientists, process engineer, the supplier, fabricator, materials engineer, design engineer, and the manufacturer and user. To date, our work on high-temperature superconductors has been entirely self-funded and has focused primarily on process and manufacturing technology rather than the discovery of entirely new materials.

Allied-Signal Aerospace put together a team and responded to the DARPA-brought agency announcement in June of 1987. This team is led by AiResearch, Los Angeles Division, and includes the

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Engineered Materials Research Center and Supercon Incorporated, a small business located in Shrewsbury, Massachusetts.

The proposed two-year program would develop a high-volume, powder production process, make wires, tapes, and ribbons, and fabricate for demonstration a 3-kilowatt, 140,000 rpm motor. This motor design is based on an AiResearch motor from a prototype flight cryocooler currently scheduled for a space application.

While it is true that this program is aimed primarily at military applications, the technology developed will have an impact on our commercial motor market, giving this DARPA program maximum potential for dual use.

In January of this year, DARPA announced their selection of 21 original contractors, including Allied-Signal. Today, however, we are not yet under contract since we had not begun negotiations prior to the May 20 freeze. At this time, most of the DARPA contractors, ourselves included, are working at risk in an effort to keep this momentum going.

We have come to realize that high-temperature superconductors will not be an immediate boon to society with major near-term commercial uses. The low current densities achieved to date, the fabrication problems, and the environmental degradation problems all combine to put limits on what can be done. But within these limits we do have opportunities.

Recent work has lowered the annealing temperature for thin films from 900 degrees centigrade to 400 degrees centigrade. In our motor application for the DARPA program, we only need current densities in the range of 500 to 1,000 amps per square centimeter at 77 degrees Kelvin. That is achievable. We already know how to make uniform fine submicron powder. What is missing is the step to convert the powder to a wire and the ability to make a device from this shape.

In the near term, we believe it will be more practical to have applications for use in space or aerospace where cryogenic temperatures are likely and will help overcome some of the near-term problems like the low current density. By their very nature, these types of applications tend to be defense oriented, but we believe the technology learned will form the basis for work in commercial markets.

Our interaction with Government agencies on high-temperature superconductors has been in participation in several Department of Energy review sessions conducted by the Office of Basic Energy Sciences as well as participation in the joint EPRI–DOE assessment of energy productivity applications of superconductors.

One excellent source of high-temperature superconductor information has been the newsletter "High Tc Update" published by Dr. Ellen Feinberg at Ames Laboratory for the Office of Basic Energy Sciences.

Allied-Signal has worked with the National Laboratories on other types of technology transfer in the past, and, based on this, I would like to offer some comments. We have worked with Oak Ridge National Laboratory on ceramics and high-temperature materials, Argonne National Laboratory on the monolithic solid oxide fuel cell, and with Los Alamos National Laboratory on ceramics, armor systems, and laser systems.

First, tech transfer is a new activity, and it will take time to develop a workable system. It is difficult to legislate a change in the way the labs have operated. It will take time for the cultural mindsets to change.

Technology transfer, despite startup problems, shows enormous promise. It should be encouraged to continue and to grow.

The variety of transfer approaches used by the labs, however, make it difficult for industry, since we must constantly adapt to different and changing styles, depending on who we're dealing with. This may be a problem, particularly for small businesses.

We are also concerned about requirements for the payments of money up front for technology developed with Government funds. This does not mean we object to paying for reasonable administrative costs associated with technology transfer or to payments of royalty after commercialization. We receive transfer technology at a fundamental stage and must spend a lot of money to develop it for commercial sale. The payment of large licensing fees up front decreases the attractiveness of technology transfer.

All of the regulations governing the interfaces between labs and industry are acquisition regulations pertaining to situations in which the labs are the buyer and industry the seller or where the lab has a monopoly of goods and services. With technology transfer, suddenly the roles are reversed and the labs are sellers in a competitive marketplace and industry is the buyer. The National Labs do not have the regulations, precedence, or flexibility to be able to accomplish this effectively in a competitive situation.

The technology marketplace itself is a very competitive arena. Items offered for sale will be evaluated by the buyers industry, and the buyers will drive the value of that technology either up or down, depending on their desires. As sellers, the labs should recognize this and accept it as a reality of the marketplace.

Finally, we are very concerned about exclusive licenses. If a company invests the technology for a specific market—invests to develop a technology for a specific market, it is only fair they should be able to reap a return on that investment. Licensing technology to everyone who is interested will not increase our competitiveness; it merely provides a disincentive to license in the first place.

Finally, what could we as Allied-Signal recommend to this Committee? We have seven recommendations: First, high-temperature superconductors should be reaffirmed as a national priority and funded as such; second, the manufacturing technology for high-temperature superconductors and cryogenics should receive more research attention; third, the DARPA high-temperature superconductor program which focuses on manufacturing technology should be given a high priority; the dual-use nature of the technology developed by DARPA and the Department of Defense should be acknowledged and encouraged; a set of uniform guidelines to govern technology transfer from the national laboratories to industry should be formulated; DOE should be encouraged to fund universities and industry in addition to the National Labs and the superconducting research centers; and, last, exclusive licenses for technology for specific markets should be encouraged.

Thank you.

[The prepared statement of Mr. Conrad follows:]

TESTIMONY ON SUPERCONDUCTIVITY TECHNOLOGY TRANSFER

BY DAVID CONRAD

ALLIED-SIGNAL AEROSPACE COMPANY

PREPARED FOR:

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

JUNE 23, 1988

I am pleased to appear before the Energy Subcommittee of the House Committee on Science and Technology on behalf of Allied-Signal Aerospace Company to discuss superconductivity and its impact on the industrial base. We appreciate the continued interest of this Subcommittee in what we feel to be a critical technology for the United States. While a lot of attention is being paid to the basic scientific research, the manufacturing technology to fabricate the materials needs attention also. We believe that Allied-Signal Aerospace can play a major role in this as detailed below.

1. WHAT IS THE SIGNIFICANCE OF HIGH TEMPERATURE SUPERCONDUCTORS?

   With a bang of publicity in the popular press and wild enthusiasm in the scientific community, the era of High Temperature Superconductors (HTSC) was ushered into being in February 1987. HTSC became an issue of national pride, and national urgency leading some to say that the development of high temperature superconductors was a test of whether the United States could compete in a world of technology. The crest was reached on July 28/29, 1987, when the Department of Energy, assisted by the Department of Defense and the Department of Commerce, held the Federal Conference on the Commercial Applications of Superconductivity. At this conference President Reagan announced his eleven point initiative to support superconductivity, to make the technology development a national priority, and to win the global race.

Despite all the hype and accompanying skepticism, there is tremendous potential for the use of HTSC. We hear a great deal about the work done by the Japanese, but developing HTSC is a global competition with many countries working hard to win a share of the market. A good deal of study has been done on the commercial market for HTSC, and the numbers vary over a wide range. There is no question, however, that a large market will exist if we can learn to fabricate and use these materials.

2. WHERE DO WE STAND ON DEVELOPING HTSC?

A year after the announcement of the Presidential Initiative, where does the United States stand?

- The DARPA High Temperature Superconductor Program has been stopped due to the 20 May Taft Memorandum with only two contracts out of twenty-one original selected contracts signed.
- DOE has performed an assessment and placed their money into the national labs/Superconductivity Research Centers.
- Several new compounds have been developed besides the original yttrium-barium-copper oxide.
- Some significant advances have been made by industry laboratories such as AT&T Bell Labs (wire) and IBM's Thomas Watson Labs (thin films on barium titanate).
- A great deal of money is being spent on basic research, but little on the manufacturing technology necessary to bring HTSC to the commercial market.

- Very little effort has been expended on the one system needed to make HTSC a practical reality - cryogenics.
- The very competitive nature of the HTSC development and the large market potential make technology transfer a difficult task.

3. ALLIED-SIGNAL AEROSPACE SUPERCONDUCTIVITY

Traditionally our involvement with this technology has been as a manufacturer using superconducting materials. AiResearch Los Angeles Division, for example, used superconducting niobium titanium wire to wind a 3,000 horsepower motor which was delivered to the U.S. Navy's David Taylor Research Center in 1980.

Our perspective on HTSC has changed some from this manufacturing viewpoint. Today within Allied-Signal, we have put together the type of team we feel is essential to commercializing HTSC.

This team consists of the scientist, the process engineer, the supplier, the fabricator, the materials engineer, the design engineer, and the manufacturer/user. It takes an iterative effort on the part of this entire team to develop and supply the raw material with the right characteristics, develop the design which takes into account the peculiar characteristics of the materials, and to develop the manufacturing technology to make a quality product.

The Engineered Materials Research Center in Des Plaines, Illinois, headed by Dr. Mary Good, and the Allied-Signal Corporate Technology Laboratory in Morristown, New Jersey, headed by Dr. Lance Davis, together supply the science, chemistry, fabrication, and materials expertise. The operating divisions of Allied-Signal Aerospace, such as AiResearch Los Angeles Division, supply the fabrication, materials, design, and manufacturing expertise as well as cryogenic systems experience. To date our work on HTSC has been entirely self funded and has focused primarily on process and manufacturing technology, rather than the discovery of entirely new materials.

4. ALLIED-SIGNAL AEROSPACE/DARPA PROGRAM

In the spring of 1987, the Defense Advanced Research Projects Agency (DARPA) released a Broad Agency Announcement (BAA) for the processing, fabrication, and demonstration of HTSC. Allied-Signal Aerospace put together a team and responded to the BAA on June 24, 1987. This team is led by AiResearch Los Angeles Division and includes the Engineered Materials Research Center (EMRC) and Supercon Incorporated, a small business located in Shrewsbury, Massachusetts. The role of EMRC will be to produce submicron size yttrium-barium-copper oxide (1-2-3 powder) powders, characterize these powders, and work on scale-up of the powder production process. In parallel, but with internal funding, they would also work on spinning fibers of the 1-2-3 powder. Supercon Incorporated

has been involved in the manufacture of low temperature superconducting wire for 25 years and they are a recognized leader in the manufacture of fine filament niobium titanium. Supercon's role on the DARPA team is to manufacture and test wires and ribbons using the 1-2-3 powder supplied by EMRC. AiResearch's role in the DARPA program is to make cylinders and disks using technology from our ceramic heat exchanger work and to fabricate and test a 3 kilowatt, 140,000 revolutions per minute (RPM) motor. This motor design is based on an AiResearch motor from a prototype flight cryo-cooler used in a space application. AiResearch will also evaluate the use of HTSC materials for electromagnetic coupling, electric motor commutators, magnetic bearings, and scale-up of these devices. The proposed program duration is two years. While it is aimed primarily at military applications, the technology developed will have an impact on our commercial motor market giving this DARPA program maximum potential for dual use.

On January 25, 1988, DARPA announced their selection of 21 contractors including Allied-Signal Aerospace. Today, however, we are not yet under contract since we had not begun negotiations with the contract agent, the Office of Naval Research (ONR), prior to the May 20, 1988 memorandum from the Deputy Secretary of Defense William Taft IV deferring all RDT&E contracts until July 1, 1988, as a minimum.

5. APPLICATIONS

In the spring of 1987, we heard of numerous "imminent" applications of HTSC, such as high speed magnetically levitated trains and new small high speed computers. However, as the reality of the problems with the new superconductors became more apparent, the applications talk quieted down. We have come to realize that HTSC will not be an immediate boon to society with major near-term commercial uses. The low current densities achieved to date, the fabrication problems, and the environmental degradation problems all combine to put limits on what can be done today. Within these limits, however, we do have opportunities. Recent work has lowered the annealing temperature for thin films from 900 C to 400 C. In our motor application we only need current densities in the range of 500 to 1000 Amps per square centimeter at 77 K which is achievable. We already know how to make uniform fine submicron powder. What is missing is/are the step(s) to convert the powder to a wire, tape, or ribbon and the ability to make a device from these shapes. In the near-term, we believe it will be more practical to have applications for use in space or aerospace where very low cryogenic temperatures will help overcome some near-term problems like low current density. By their very nature these types of applications tend to be defense oriented, but we believe the technology learned will form the basis for work in commercial markets.

6. TECHNOLOGY TRANSFER

As far as technology transfer goes, we have followed the published information on superconductivity ranging from the Wall Street Journal and New York Times to the Physics Review Letter. We have, naturally, participated in major technical conferences. Our interaction with government agencies on HTSC has been limited to participation in several Department of Energy (DOE) review sessions conducted by DOE's Office of Basic Energy Sciences and participation in the joint EPRI/DOE Assessment of Energy Productivity Applications of Superconductors held in April 1988. One excellent source of HTSC information has been the newsletter, "High Tc Update," published by Dr. Ellen Feinberg at Ames Laboratory for DOE's Office of Basic Energy Sciences.

Allied-Signal Aerospace has worked with the national laboratories on other types of technology transfer, and I would like to offer some comments based on our experiences. We have worked with Oak Ridge National Laboratory on ceramics and high temperature materials, with Argonne National Laboratory on the Monolithic Solid Oxide Fuel Cell, and with Los Alamos National Laboratory on ceramics, armor systems, and laser systems.

- Technology transfer is a new activity, and it will take time to develop a workable system.
- It is difficult to legislate a change in the way the labs have operated; it will take time for the laboratory mind sets to change.

- Technology transfer, despite start-up problems, shows promise; it should be encouraged to continue and to grow.
- The variety of transfer approaches used by the labs make it difficult for industry, since we must adapt to different and changing styles. This may be a problem particularly for small businesses.
- We are concerned about requirements for the payment of money up front for technology developed with government funds. This does not mean we object to paying for reasonable administrative costs associated with technology transfer or to payment of royalties after commercialization. We receive the transferred technology at a fundamental stage and must spend a lot of money to develop it for commercial sale. The payment of large licensing fees up front decreases the attractiveness of technology transfer.
- All of the regulations governing the interfaces between labs and industry are acquisition regulations pertaining to situations in which the labs are the buyer and industry, the seller; or where the lab has a monopoly of goods and services. With technology transfer suddenly the labs are sellers in a competitive marketplace and industry is the buyer. The national labs do not have the regulations, precedents, or the flexibility to do this effectively and to accommodate the buyer.
- The technology marketplace is a very competitive arena. Items offered for sale will be evaluated by

the buyers, and the buyers will drive the value of the technology up or down. As sellers, the labs should recognize this and accept it as a reality in the marketplace.

- We are very concerned about exclusive licenses. If a company invests to develop a technology for a specific market, it is only fair they be able to reap a return on that investment. Licensing technology to everyone who is interested will not increase our competitiveness, it merely provides a disincentive to license in the first place.

7. WHAT DO WE RECOMMEND?

- High temperature superconductors should be reaffirmed as a national priority and funded as such.
- The manufacturing technology for HTSC and cryogenics should receive more research attention.
- The DARPA HTSC Program, which focuses on manufacturing technology, should be given a high priority.
- The dual use nature of the technology developed by DARPA and the Department of Defense should be acknowledged and encouraged.
- A set of uniform guidelines to govern technology transfer from the national labs to industry should be formulated.
- DOE should be encouraged to fund universities and industry in addition to the national labs.
- Exclusive licenses for technology should be encouraged.

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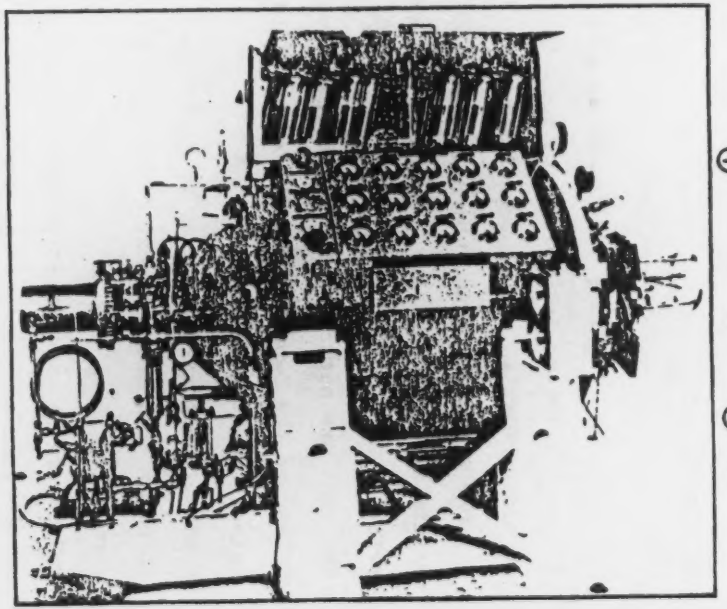
SUPERCONDUCTOR MAKES ELECTRIC MACHINES MORE EFFICIENT



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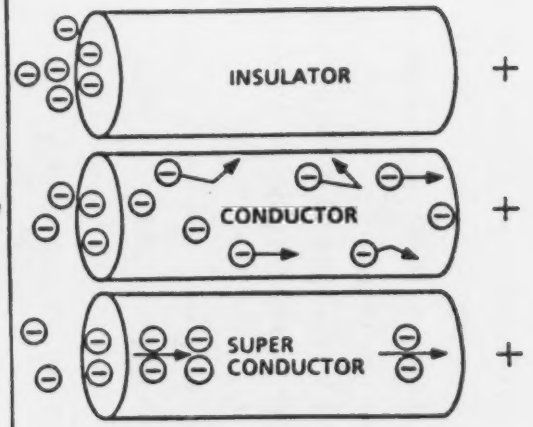
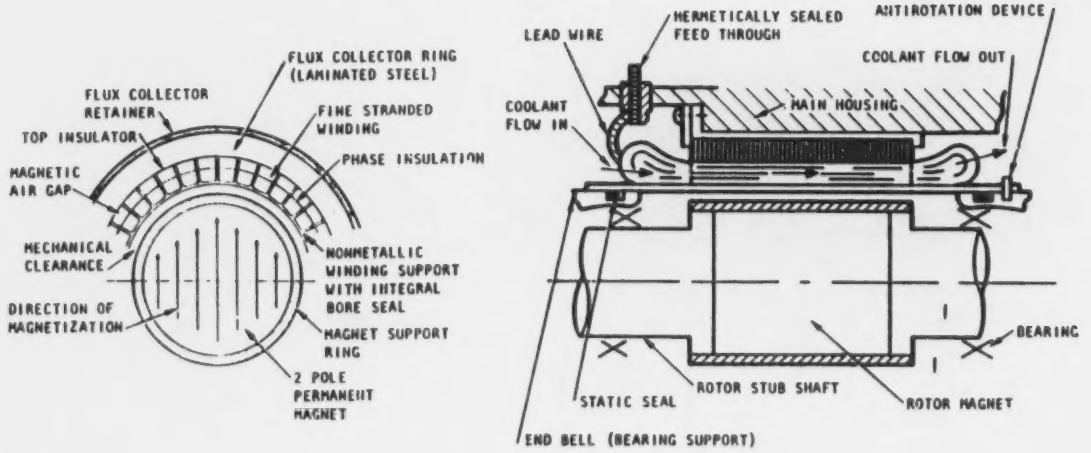
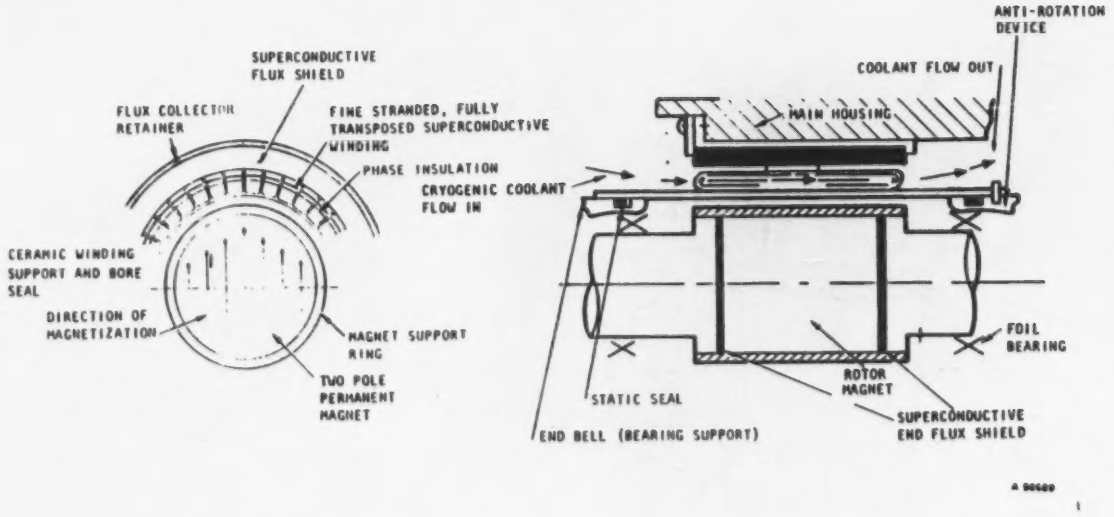


ZERO RESISTIVITY

Allied Signal

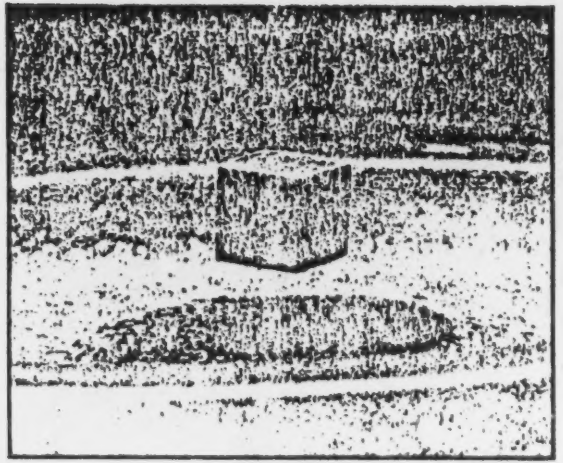


Design Details on Existing Toothless Stator, Two-Pole PM Rotor Machine

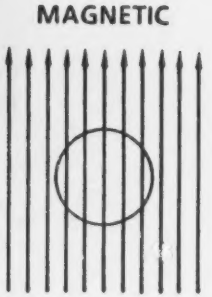


Superconducting Toothless, Ironless, Two-Pole PM Machine

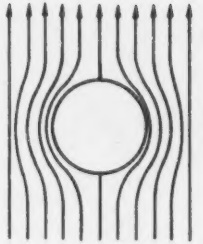
DIAMAGNETISM IS KEY TO LEVITATION



LEVITATED CUBE



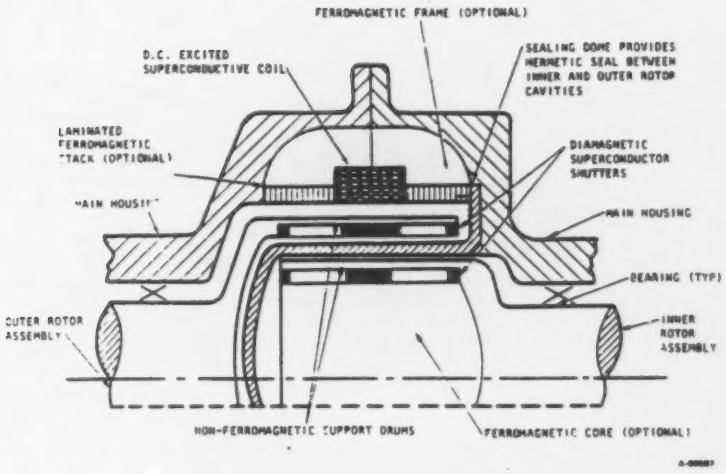
NORMAL



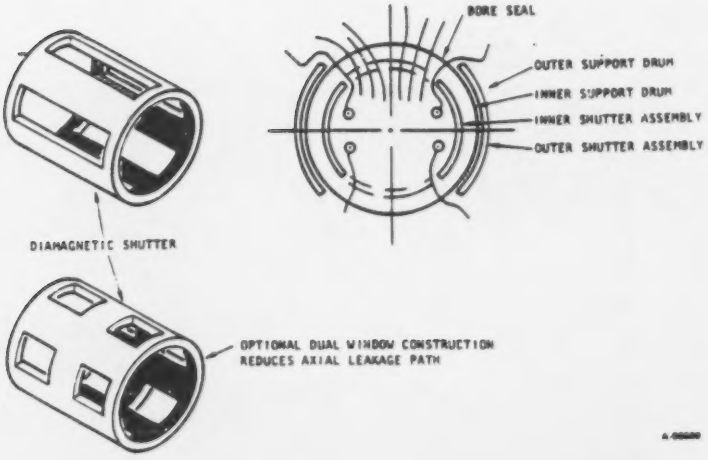
SUPER CONDUCTOR

DIAMAGNETIC PROPERTY

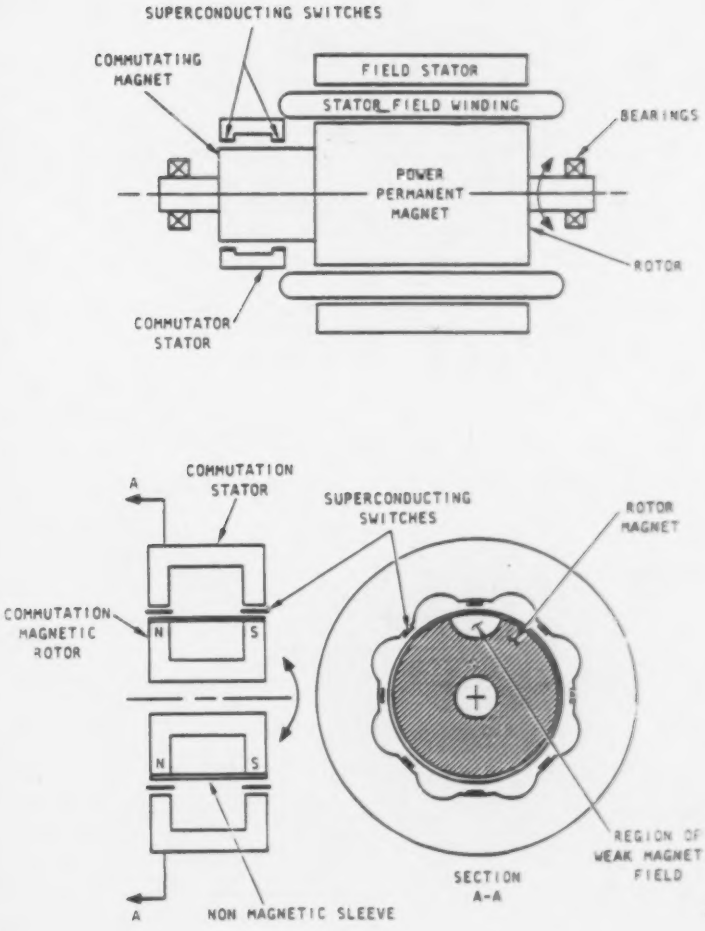
Allied Signal



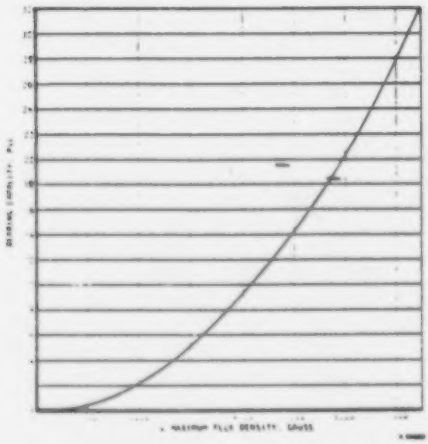
Diamagnetic Superconductor Torque Coupling, Cross Section



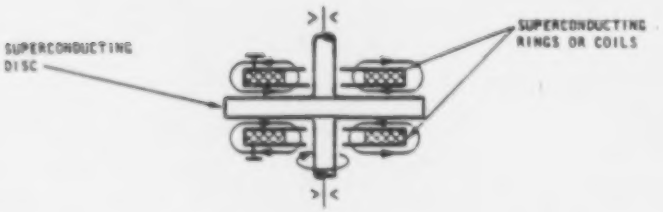
Diamagnetic Superconductor Torque Coupling
Details and Principle of Operation

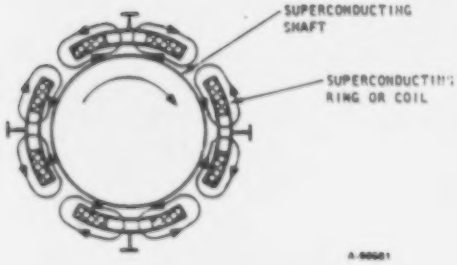


Superconducting Commutator using Meissner Effect



Bearing Capacity for Superconducting Magnetic Bearings





Superconducting Magnetic Bearings

TABLE 1

SUPERCONDUCTOR CHARACTERISTICS REQUIRED

Application	Configuration		Characteristics			
	Wire	Bulk	High Ac Current Density	High Dc Current Density	Diamagnetism/ Meissner	Zero Resistivity
High-speed motor	X	X	X	N/A	X	X
Electromagnetic coupling	X	X	N/A	X	X	X
Motor commutator	N/A	X	X	N/A	X	N/A
Magnetic bearings	N/A	X	N/A	X	X	N/A

Mrs. LLOYD. Thank you very much.

Gentlemen, we are about to run out of time. I'm going to ask you if you would, each one of you, relate what you feel is the number one problem in your relationship with our National Laboratories in technology transfer, exclusive licensing, funding, Freedom of Information, whatever it may be. That's my question to you—if you had one thing you wanted to change.

Dr. BLACK. As we have not had the experience of a technology transfer arrangement with the national laboratory it's a little hard to answer the question, but from what I have heard today it sounds as though the concept of exclusivity is accepted by the laboratories, and I think that that must be a very important factor.

I know as a small business, if we were to be approached, as we have been, by some of the people at the National Laboratories, and they have some good ideas which we believe we could incorporate into our product technology and market successfully, I know that it would take a large investment for us to take those good ideas and get them into the marketplace, and I think the concept of exclusivity, to give us a chance to reap the rewards of the effort that we would have to put forth to make the technology useful, would be essential.

Mrs. LLOYD. Dr. Eror.

Dr. EROR. In our case, the technology was created by us first, so we haven't had problems with the transfer, except the direction. We really need the funding to get under way, and the National Laboratories have been cooperative, particularly Los Alamos. We have a good working relationship. We just need to be able to bring more to the table so that we can get on with it. We have also interacted with other laboratories, at Argonne National Laboratory, both for information and some tests and always found them cooperative.

Mrs. LLOYD. So you would list funding.

Dr. EROR. Yes.

Mrs. LLOYD. Mr. Lloyd.

Mr. LLOYD. We have done some work with Oak Ridge National Labs on some energy conservation programs, and it's worked out fairly well with us. On the superconductivity program, I just met with them yesterday, and there again we did get into some of the problems of lawyers looking for exclusive rights since they didn't get total agreement, so we couldn't completely discuss everything that both companies were doing. But that gets to be one of the problems, is the exclusivity of different companies' rights.

Mrs. LLOYD. Mr. Conrad.

Mr. CONRAD. I think the one thing that I would change is, I would ask for technology transfer guidelines which are uniform for all labs, which recognize the competitive nature of this marketplace where industry is now the buyer, which recognize the need for exclusive licenses for specific markets, and which recognize the fact that industry needs to put up a lot of money to finally commercialize what technology they're getting transferred from the labs and not require up-front fees other than reasonable administrative costs.

Mrs. LLOYD. Thank you.

Mr. Morrison.

Mr. MORRISON. I understand the need for exclusivity. How might we divide, if you will, a technology—how would you determine who should get the exclusive rights, in your experience, Mr. Black?

Dr. BLACK. That's, of course, a very difficult question. In many cases, at least to draw on personal experience, we have a specific kind of business that we're involved with, and we need to have the exclusive rights in that marketplace. That's the key thing for us as a company that is trying to sell the fruits of technology. It's the end product that really counts. So exclusivity with respect to the market, with respect to the applications, those are the things that are important.

Now we happen to be in a situation where there are no real competitors yet, and, as a result, if such technology was available and we were to walk into the supermarket and select it off the shelf and say, "We want to use it for this application," I doubt that anyone else would be competing with us. So maybe the question wouldn't come up.

To a certain extent, the answer might be who shows the initiative to go in and ask and say, "Look, you guys have got something that's interesting, something that we could use, we want it," and I think that perhaps first come/first served may be the best thing. The only issue then is how to disseminate the information so that everyone who is interested has a chance to be first, and I think that maybe that's part of the task—business's task is to be aware of what's going on.

Mr. MORRISON. Mr. Conrad, you want a list of rules to determine precisely how this transfer process works. In your experience, should we be writing those into law, or should those be regulations as put together by the Department of Energy?

Mr. CONRAD. I think those should best be handled as regulation. I think what's missing is—what's needed is not so much an ironclad set that says you must do this, but what is needed is to allow the labs the flexibility and the capability to cut some of the red tape that we've heard discussed today.

Mr. MORRISON. Madam Chairman, just to comment. I'm pleased that you've brought all elements together today, and I think we've gotten some excellent information, and I want to add my voice in appreciation for everyone. We have the vendors, and we have those of you that are knocking on the door, and somehow we can help ease the way for the application of these new technologies.

I yield back.

Mrs. LLOYD. I agree with you. Our testimony has been excellent. I think it paves the way for a lot of work for this Committee.

Mr. Fawell.

Mr. FAWELL. Thank you. Only one question.

Mr. Conrad, you indicated that there are large up-front licensing fees being charged. Is that true of the labs at this point?

Mr. CONRAD. That specifically relates to one technology program that we have been working with Argonne National Labs, where there was some discussion—at this point, we're kind of in a lull—there was some discussion of paying a licensing fee in the neighborhood of $100,000 up front to ARCH to receive the technology.

Mr. FAWELL. And you also in your statement referred to exclusive licenses for technology. I see in your oral testimony you added "for specific marketplaces." I don't know that much about exclusivity insofar as licenses are concerned, but you look at superconductivity and you realize the tremendous potential, the end products of which we perhaps can't even see at this point. It's pretty difficult to give exclusive licenses. You don't know what you're giving, but one entity—unless you could break it down, and I gather in Congressman Morrison's statement he was referring to that. You divide the exclusivity into parts?

Mr. CONRAD. I think the question of exclusivity is based on what the technology is. That's really going to determine whether it's feasible or practical to give exclusive licenses.

For example, in the case of the monolithic fuel cell where we are working towards an exclusive license for the aerospace market because we're an aerospace company, that's something where we can point and say, "Here's a specific example of exclusivity," and my comments on technology transfer today were not necessarily related exactly to superconductivity, because our tech transfer to date with the national labs on the subject of superconductivity has been mostly verbal—you know, here's what we're doing; here's what they're doing type situation. We're getting down to specifics on other programs like the fuel cell where we are dealing in the idea of exclusive licenses for a specific market.

Mr. FAWELL. Fine. Thank you.

Mrs. LLOYD. Thank you very much. Our testimony has been excellent today, and although we can't predict the outcome of this race, I think one thing is for sure, that we do have so many quality players on the Government-industry team, and certainly the Subcommittee will act to improve on the programs and processes where we can help the DOE laboratories transfer the technology to the marketplace. I wish all of you well, and certainly this Subcommittee wants to help all of you to expedite this process not only for the good of your industries and the good of the labs but for the good our country and the good of all mankind.

Our next hearing will be on the 30th, when we will take up the Renewable Energy and Energy Conservation, Commercialization, and Development Act. If there is no further business, I thank all of you. The Subcommittee stands adjourned.

[Whereupon, at 12:30 p.m., the Subcommittee was adjourned.]

APPENDIX

Additional Statements for the Record

Statement of

Donna R. Fitzpatrick

Assistant Secretary for Conservation

and Renewable Energy

Before the

Committee on Science, Space, and Technology

Subcommittee on Energy Research and Development

U. S. House of Representatives

June 23, 1988

Madam Chairman and distinguished members of the Committee:

It is a pleasure to be here to discuss the Department of Energy's high temperature superconductivity applications research and technology transfer efforts.

Overview of Superconductivity Research

The Department has had a long-standing involvement in superconductivity because of the potential payoffs across a broad spectrum of research including high energy physics; fusion energy; and electric power production, storage, and distribution. As an example, the Tevatron accelerator located at DOE's Fermi National Accelerator Laboratory is the largest superconductor project in the world. The Office of Energy Storage and Distribution has 15 years of research experience in superconducting generators, transmission, and storage systems.

When it was announced that new high temperature superconducting materials had been discovered, shattering all previous conceptions about the limitations of superconducting materials and applications, the Department of Energy was ready to respond to the technical challenges. Funding and research programs were rapidly adjusted to take advantage of the new discoveries. DOE also moved to establish new institutional relationships and mechanisms to assist and involve industry in developing and exploiting these new materials. With the help of a key national resource, the National Laboratories, and the guidance and participation of industry, the Department of Energy is now working to develop a technology base in high temperature superconductivity which can be put to practical use by industry.

Many basic and applied research challenges must be met before industry can realize significant market benefits from high temperature superconducting products. Yet because their potential is so vast and international competition in the field is so fierce, it is crucial that the U.S. forge ahead in commercial applications and technology transfer to industry as well as basic research. High temperature superconductors may well open a new era in supercomputers; in electricity transmission and storage; in magnetic levitation propulsion; in powerful, compact motors; and in instrumentation and research equipment capable of probing everything from subatomic particles to the inner workings of the human body.

The Department's superconductivity research has focused on understanding the materials and phenomena of superconductivity and applying the technology of superconductivity to the Department's programs in fusion, accelerator physics, and electrical energy storage and distribution systems. DOE is exploring the potential of high temperature materials in electronic devices, energy storage and distribution, and high energy magnets, with the active involvement and support of industry. The Department's superconductivity research efforts are critical to sustaining progress in both basic theory and applications of the new high temperature superconductors by industry. U.S. research is leading the search for better superconducting materials and ways to turn them to practical advantage.

Although the focus of today's hearing is on applications research, it is important to recognize the value of more fundamental research in sustaining and improving applications efforts. Practical high temperature superconducting devices are still far from reality. How this new class of superconductors work is not yet completely understood. Thus DOE's research on

the fundamental structure and behavior of the new materials has strong potential for producing a theory of how high temperature superconductors work, which can be used to guide work in manufacturing and applications.

Key Technical Issues

DOE's research efforts are aimed at resolving complex and often interrelated scientific and technical challenges. A material's superconducting properties are generally limited by temperature and current. Temperature constraints have now been raised to 125° Kelvin (-148°F), a temperature easily reached by cooling with liquid nitrogen, but still far below room temperature. Current density is one of the main constraints on new superconducting materials applications. The present critical current density for bulk high temperature superconducting materials must still be increased by a factor of 1000 for many power system applications.

In addition to limits on the new materials' superconducting properties, there are also mechanical limitations such as brittleness, chemical instability, and difficulty in manufacturing useful shapes. Fabrication and processing techniques for the new superconductors are expected to be vastly different from current techniques used to manufacture wires, thin films, and other products that new superconductors may someday replace.

Overview of DOE Programs

In FY 87 approximately $40 million was expended by DOE on superconductivity research and technology transfer, more than one-quarter of that total on high temperature superconductors. In FY 1988 funding increased to approximately $60 million, split almost half and half between "low" and "high" temperature superconductor research, more than doubling high

temperature superconductivity research funding. The funding was divided among efforts by the Offices of Basic Energy Sciences, Fusion Energy, High Energy Physics, Fossil Energy, Conservation and Renewable Energy, and Defense Programs. The Office of Basic Energy Sciences is responsible for fundamental research efforts aimed at understanding the structure and properties of the new materials. Research in the Offices of Fusion Energy, High Energy Physics, Fossil Energy, and Defense Programs is focussed on particular applications pertinent to their program areas.

Under the President's Superconductivity Initiative the Department established three centers to conduct research and disseminate information on superconductivity. The Argonne center is actively investigating applications such as magnets, for accelerators and medical imaging devices, and conductors for electrical power transmission, storage, and conversion. The Lawrence Berkeley Laboratory's research emphasizes applications of high temperature superconductors in electronic devices such as radiation detectors, magnetic field sensors, and computer circuitry. Ames National Laboratory is coordinating information dissemination activities on the fundamental and generic properties of the new high temperature superconductors. In addition to the three centers, the Office of Scientific and Technical Information (OSTI) has established a computer database that industry can access to learn about work in progress at the laboratories and in industry. The President's Executive Order No. 12591 directed DOE to grant patent waivers and to assign patent rights to industry, universities, and Labs to the extent permitted by law.

Office of Energy Storage and Distribution

The Office of Conservation and Renewable Energy, in which I am directly involved, funds research in the Offices of Energy Storage and Distribution and of Energy Utilization Research aimed at particular applications of superconductivity.

The Office of Energy Storage and Distribution is responsible for the development of reliable, safe, low-cost, and environmentally sound energy storage and distribution systems. The Office's power delivery technology research includes superconducting transmission cables; superconducting electrical energy storage systems; superconducting generators, motors, and transformers; and control and protection devices that would be associated with superconducting technologies. In FY 87, the Office of Energy Storage and Distribution conducted an economic assessment of the potential for applying new high temperature superconducting materials in devices previously developed with low temperature superconducting materials and found significant opportunities. But if these opportunities are to be realized, the current density of the new materials must be improved and the new materials must be fabricated into useful and durable shapes. Earlier successful applications research for low temperature superconductors for generators, ac transmission lines, and magnetic energy storage proved a significant advantage in assessing the potential of the new materials. The earlier research illuminated significant technical and economic issues related to the use of superconducting devices by electric utilities. Although at the time they were investigated these low temperature applications were unable to compete successfully in the market, the use of high temperature superconductors within the same devices and configurations offers a promising avenue for introducing the new materials into the marketplace.

For FY 88 $4.4 million has been devoted to prototype high temperature superconductor equipment development within the Office of Energy Storage and Distribution. The initial effort focused on developing practical superconductors which can carry sufficient current loads and that have the strength, ductility, and stability required by utility applications. Parallel research is being carried out on the technological characteristics of devices designed to take advantage of the new high temperature superconductors. This work will aid in designing devices especially adapted to the unique characteristics of the new superconductors and define materials characteristics that researchers must strive to achieve.

The Department recently selected ten Laboratories for funding to pursue expanded research in the development of practical high temperature superconductors. The research will include development of a superconducting wire as well as thin and thick film conductors, new concepts in processing and fabrication, and new approaches for producing special devices for power systems. The proposals include an innovative requirement that research teams be composed equally of representatives from the private sector, universities, and government laboratories. Research efforts at Ames National Laboratory include the development of novel approaches for fabricating high temperature superconducting monofilaments by combining the new materials with normal metal in order to create a flexible wire. Argonne is investigating superconducting tapes, thin films, and wires and has fabricated several products which show high potential for practical applications. A thin film deposition technique for applying superconducting films to electronic devices has also been developed by Argonne. Brookhaven is looking at the practical considerations involved in making magnets from the new superconducting materials. Los Alamos is investigating fabrication options such as melt texturing, vapor deposition,

and powder consolidation for manufacturing superconducting devices. Lawrence Berkeley is researching thin film superconductors deposited via sputtering, pulsed laser ablation, and sol-gel processing. Lawrence Livermore is involved with explosive compaction techniques for forming superconducting wires, which shows promise for improving current flows within the new materials.

Office of Energy Utilization Research

The Office of Energy Utilization Research, Energy Conservation and Utilization Technologies (ECUT) program, also conducted a preliminary assessment of the energy conservation potential of the new high temperature superconductors in FY 87. In FY 88, ECUT is conducting a more detailed assessment of the new materials in nine specific areas: transportation, motors, heat pumping, power electronics, lighting, electromagnetic pumping, materials production, materials fabrication, and waste separation. Half of the funds for the assessment are being provided by the Electric Power Research Institute and the other half by the Department. Once the assessment is completed an experimental program will be planned and industry participation will be solicited, probably later this year.

Research Coordination

Superconductivity research efforts within DOE are coordinated by the Energy Materials Coordinating Committee, subcommittee on superconductivity. The subcommittee actively reviews the various program efforts and provides guidance on improving program operations and inter-program coordination.

Outside DOE, related applications and basic research is being conducted under DoD, NASA, the National Science Foundation, and National Bureau of Standards auspices. The government's overall superconductivity research

efforts are being coordinated and information is being exchanged under the oversight of the White House Office of Science and Technology Policy. The Office has organized a subcommittee on high temperature superconductivity that now includes representatives of ten agencies. The subcommittee has played an important role in guiding overall research efforts. Efforts by other agencies that are of particular interest to DOE program efforts include the Strategic Defense Initiative Organization's research into superconducting magnetic energy storage. The Electric Power Research Institute has become involved in sponsoring this storage research because of its possible value in peak power storage applications for the electric utility industry. Basic materials research sponsored by the National Science Foundation has potentially wide impacts on the entire spectrum of high temperature superconductivity research and is of great interest to the Department of Energy.

Industry Efforts

In the private sector a variety of innovative small- and medium- and large-sized firms are developing superconducting materials, fabrication techniques, and devices. Recent developments include fabrication of a thin film device for a highly sensitive magnetic detector and production of a single superconducting crystal capable of handling 100 times more current than any previous high temperature superconducting material. Various firms have successfully manufactured prototype superconducting tapes, magnets, and wires from the new materials. A company involved in low temperature superconductivity research recently released an oscilloscope that uses superconducting components that make it much cheaper and many times more sensitive than its closest competition, demonstrating that superconductivity

has a high potential even without high temperature materials. Superconductivity research consortium are forming and companies are actively investigating research alliances.

Cooperative Research

The Department's established technology transfer efforts and the President's initiative emphasize industry involvement and access to the results of DOE's research. As a result, the Department has oriented its efforts to involving and serving industry to the maximum extent possible. New cooperative research pilot centers at Los Alamos National Laboratory, Argonne, and Oak Ridge are being organized, in addition to the research centers established by the President's superconductivity initiative, in order to speed up the research-to-application cycle. The express purpose of these new centers will be to seek out and grasp opportunities for cooperating with industry in order to improve technology transfer. The center's cooperative research efforts are expected to attract significant industry co-funding, and investigate approaches to speeding up the contracting and project approval process, and expedite the transfer of patent rights and other intellectual property. The pilot centers will provide a new opportunity to mobilize the expertise into areas identified as priority research from their perspective of forging commercial products.

DOE believes that cooperative efforts in high temperature superconductivity have a very high potential because of the mutual benefits to be gained by both industry and government. High temperature superconductors are in the very early stages of development and will require a long term, substantial commitment to research in order to reach their full potential.

Many companies may find it difficult to make a substantial commitment on their own, but would be willing to participate if the government or other industry partners were sharing part of the burden. Also, high temperature superconductors have extremely high market potential and competition is likely to be substantial. Major international research efforts in high temperature superconductors are already organized. The National Laboratories have a wealth of technical expertise, equipment, and experience in superconductivity applications already in place that could be of great value to industry. All the elements for successful cooperation exist, if the Department and the Laboratories can create the right environment for cooperation.

Issues in Technology Transfer

Although there are clear benefits to be gained from cooperation between DOE and industry, there are also significant impediments. The Department of Energy, industry, and the Laboratories are concerned about the effectiveness and timeliness of procedures for arranging cooperative agreements. Because research developments are occurring so rapidly, cooperative research agreements need to be arranged quickly, and also need to be flexible enough to adjust and take advantage of outside developments as they occur. The Department is moving on a broad front to streamline and improve contracting and other procedures governing cooperative research.

Another basic issue is the tradeoff between a company's desire to access and profit from cooperation and information-sharing to the maximum extent possible versus its equally strong desire to protect proprietary information. In addition, DOE and the private sector have both had difficulty in balancing the value of open information flow with companies' desire to protect and

profit from jointly generated, non proprietary information. A significant part of the Department's technology transfer effort is aimed at solving these problems by providing companies with stronger safeguards for proprietary information contributed to cooperative research and by making it easier for industry and the Laboratories to acquire and develop the results of cooperative research. At this early stage of development in superconductivity it is important to maintain and expand cooperative efforts and encourage the free flow of information between government and industry researchers.

I hope I have been able to provide you with the general thrust of what DOE has accomplished and the directions in which DOE's high temperature superconductivity research is heading. The Department is dedicated to creating a supportive, creative program for developing and applying high temperature superconductors in the Nation's economic and energy infrastructure and appreciates the assistance of this Subcommittee in helping make that possible.

WRITTEN TESTIMONY TO
THE UNITED STATES HOUSE OF REPRESENTATIVES
SCIENCE, SPACE, AND TECHNOLOGY COMMITTEE

June 23, 1988

by Dr. William J. Gallagher

Manager, Exploratory Cryogenics

Thomas J. Watson Research Center

Research Division

International Business Machines Corp.

Written Testimony of William J. Gallagher, IBM Research Division to

House Science, Space, and Technology Committee

June 23, 1988

I am grateful for the opportunity to present written testimony on the subject of government-directed applications programs in high temperature superconductivity and their impact on the U.S. industrial base. I am only able to submit written testimony because a prior schedule commitment precluded me from testifying in person. My perspective in this testimony is that of a scientist who has been engaged in superconductivity research in an industrial company for ten years, and who has been an investigator and principal investigator in cost-shared research contracts with the government. My testimony will summarize the emphasis and accomplishments of IBM's research in high temperature superconductivity, how a pending cost-shared government research contract fits into these, and my evaluation of the advantages and weaknesses of this sort of government-funded research arrangements. My main messages are that these cost-shared arrangements are very good ones, but that the government fund-commitment process involves delays and uncertainties that are quite detrimental to the sought-after research results.

IBM Research has a sizable research effort in high temperature superconductivity, which is mostly internally funded. In fact, IBM Research has had a long tradition of research in superconductivity, some of which has been done with partial government support. At present in the area of high temperature superconductivity, we have active programs at Research Division laboratories in Zurich, Yorktown, and Almaden (San Jose, CA). The bulk of this research is in fundamental science. It addresses questions such as what are the properties of these new materials and what is the mechanism responsible for their superconductivity. We are also active at a rather basic level in the materials and processing science of these new materials. This is necessary in order to have good specimens for the fundamental studies, but also it is research that underlies potential applications.

Highlights of IBM research in high temperature superconductivity include the original discovery of Bednorz and Müller at our Zurich laboratory, the demonstration in Yorktown that the liquid nitrogen temperature superconductors are anisotropic (i.e. that their properties such as the ability to carry supercurrents differ in different directions), and, in Almaden, the first achievement of full superconductivity (zero resistance) at 125 K in thallium calcium barium copper oxide. In the thin film area, which is my principle area of expertise, some of my colleagues in Yorktown were the first to produce thin film specimens in which the CuO sheets were aligned enough to demonstrate that the new materials can carry usefully large supercurrents in the liquid nitrogen temperature range. Furthermore my colleague R. Koch and his collaborators here were able to demonstrate the operation of a dc SQUID in the liquid nitrogen temperature range, and we have recently measured a noise performance of $3 \times 10^{-4}\Phi_0/\sqrt{Hz}$ at 20 Hz at 77 K in a simple dc SQUID device. W.Y. Lee, J. Salem and other colleagues in Almaden have recently made TlCaBaCuO films that are fully superconducting at 120 K and using these films we are now trying to make simple dc SQUID's

that should function above 100 K. Most of this work was carried out with internal funding but the anisotropy studies and some aspects of the more recent thin film work were partially carried out under a superconducting device research cost-shared contract we have with the US Office of Naval Research.

Besides our basic research activity, we have, of course, also taken a look at potential applications. The outlook for applications in the data processing industry appears to be rather long term. This is one reason for our present focus on fundamental science and on the materials and processing science that might underlie technology. One application area that looks promising in a shorter time frame is the use of liquid nitrogen cooled superconducting sensors, particularly dc SQUID's which are very sensitive magnetic field sensors. Because of our long-standing research in superconducting electronics, particularly our digital Josephson technology explorations from 1965-1983, we have considerable expertise in the design, fabrication, and use of dc SQUID's and we are presently exploiting this expertise in scientific applications of SQUID technology with conventional superconductors. Our feeling was that focusing some of our high temperature superconducting thin film materials research effort towards this applications area would be both a good use of our internal capabilities and a good cohesive force for the thin film materials research. Our activities in such high temperature SQUID development would be undertaken more for the benefit of learning that occurs along the way, and for possible internal scientific applications, than they would for any eventual IBM product. On the other hand, success in this area could potentially lead to military if not commercial instrumentation applications, and we looked favorably on the possibility of outside funding for partial support of this research. The supplemental outside funding would enable us to put greater resources on this activity than we otherwise could. It might also lead to some earlier outlet for the technology that we might develop. This was the line of reasoning that lead us to propose a cost-shared contract that is now pending with ONR entitled, "High-Temperature Superconducting Multi-Level Materials and Device Development and Device Physics" with R.H. Koch and myself as principal investigators.

I was asked to comment on the problems and opportunities we have encountered as a result of government funded projects. I have a very favorable view of the type of government sponsored research arrangements that IBM Research generally engages in -- 50%-50% cost shared arrangements. Such arrangements insure the commitment of both parties to the research. This arrangement also allows us to get patent and data rights with which we are comfortable. For the pending high temperature superconducting device research contract we proposed an arrangement where costs are shared 51%-49% between IBM and ONR to enable us to be eligible for a government purpose licence for intellectual property, which we viewed as a slightly better position to be in to protect our investment. I also feel that these are good arrangements for the government. Besides the benefits directly written into the contract for the government, the sponsored research indirectly benefits considerably from significant resources available within IBM.

I am at present the principal investigator in an active contract IBM has with the US Office of Naval Research entitled "Three Terminal Superconducting Device Research." My experience in this cost-shared project has been a very good one in the execution phase of the contract. This project is a a rather open-ended research effort aimed at exploring some ideas for new transistors that would oper-

ate well at very low temperatures. When our research showed that some ideas we were pursuing with nonequilibrium superconductivity would result in slow devices, we were able to shift emphasis to investigations of hybrid semiconductor-superconductor device structures which seem quite interesting. Also within the contract we had the freedom to explore how the new oxide superconductors might affect this line of investigation. Initially this meant determining some of the basic properties of the new materials, and, partially under ONR sponsorship, we were able to demonstrate large anisotropy in the current density and critical fields of the new superconductors, a result which I listed above among the highlights of IBM's accomplishments in high temperature superconductivity. I have always felt that my contract officers at ONR had a very clear understanding of how basic research is conducted and how to fund such research productively.

What I am pleased with above is the execution phase of the contract. What has been a less pleasant experience has been the process of getting the contract started. This was true with my earlier superconducting device research contract and seems to be the case with the contract that is pending with ONR for high-temperature superconducting materials and device development. The problem has not been in the technical review phase of the process which, in my experience, has been efficient and reasonably timely. However, the procurement phase was very protracted in the case of the three-terminal device contract and in the pending contract seems to be moving slowly as well, with considerably uncertainty as to when the contract will actually start. In the present case with the proposed high temperature superconducting device development contract, after passing the technical review process in early March, we had indications that a contract start date of May 1 might be possible. Later this became June 1, perhaps retroactively. Then there was a moratorium on new procurements that stalled the contract negotiation process. It is not clear to me where we stand now. This makes getting off to a fast start very difficult. In our case we could have used an executed contract, or perhaps a firm indication of funding (preferably with an agreed-upon retroactive start date if the contract cannot be executed quickly), to allow us to start the processes of staffing-up and getting the equipment we need. However, the indications we had of possible starting dates have not been that firm. In the case of smaller companies that might be more heavily dependent on outside funding for expenses (and for capital as well), the uncertainty and delay must be devastating.

Before closing, I would like to make some comments about the funding situation for colleagues in my area of expertise that are in government labs. Leading-edge research by groups in thin film superconducting devices at government and university laboratories is important to industry in many ways. The funding situation for the US government's own laboratories seems to be considerably worse off than it is in many industrial labs, including perhaps even those industrial labs that are largely supported by contacts. I have talked to colleagues in the two government laboratories that President Reagan a year ago proclaimed to be "thin film superconductivity centers." These are very good labs, with top researchers in thin film superconducting devices, at the Bureau of Standards in Boulder and in the Lawrence Berkeley Lab. In both cases there seems to have been some redistribution of funds within the laboratories' own funding structures to improve the stability or capital equipment base of the superconducting film efforts. Mostly this was in line what had been requested before the discovery of high

temperature superconductivity. Plans for increased funding at a more substantial level seem to be in the FY89 budget, the outcome of which will not be known for some time. This means there is considerable uncertainty in both the intermediate and long term as to the level of funding for these groups. Under these circumstances meaningful planning is impossible. Even if healthy funding finally comes and its stability seems assured, by the time it does come, I do not see how these groups can have positioned themselves to move rapidly in this field.

In summary, I hope I have conveyed some our thinking about the directions of IBM's research in high temperature superconductivity and why and how we like to supplement our internal research funding with outside funding through cost-shared research arrangements. I have also described my dissatisfaction with the uncertainty and delays involved in the contract negotiation/funding commitment phase of the government funding process. I further described my fear that the consequences of the slow and uncertain funding process may be more severe for colleagues in other research institutions that are more fully dependent on government funding.

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